

FINAL ANNOUNCEMENT



Beltsville Symposium XV REMOTE SENSING FOR AGRICULTURE

**May 16-18, 1990
NASA Goddard Space Flight Center
Greenbelt, Maryland**

Co-Sponsored by
Beltsville Area, Agricultural Research Service
and NASA Goddard Space Flight Center
with the cooperation of
Friends of Agricultural Research-Beltsville, Inc.

Beltsville Symposium XV is cosponsored by the Beltsville Agricultural Research Center (BARC), and the NASA Goddard Space Flight Center (GSFC).

The meeting will be held May 16-18, 1990 at GSFC in Greenbelt, Maryland. These three days precede the IGARSS '90 Symposium which will be held nearby at the University of Maryland on May 21-25, 1990. This schedule will facilitate attendance at both meetings.

Due to NASA security regulations, foreign nationals MUST preregister, with registration materials due to the Symposium Committee three weeks prior to the meeting.

The symposium will consist of invited speakers, whose written papers will be published as the symposium proceedings, and poster sessions of contributed papers. Contributors for poster sessions must submit a 300 word (maximum) abstract by March 15, 1990. These abstracts will be included in the meeting program.

SCHEDULE

ACTIVITIES

Tuesday Evening	REGISTRATION Sheraton Greenbelt Hotel
Wednesday Evening	Mixer Goddard Recreation Center
Thursday Evening	BANQUET Sheraton Greenbelt Hotel
Wednesday	Symposium
Thursday	Symposium
Friday	Symposium

SPEAKERS AND SUBJECTS

G. Asrar, NASA, Washington, D.C.

Estimation of Potential Productivity of Energy and Water Limited Ecosystems from Remotely Sensed Data.

E. J. Barron, The Pennsylvania State University, University Park, PA

The Global Water Cycle and the Earth Observing System.

T. N. Carlson, The Pennsylvania State University, University Park, PA

The Radiometric Temperature of Vegetation From Space: Results of Recent Studies.

J. Cihlar, F. J. Ahern, and R. J. Brown, CCRS, Ottawa, Canada

Monitoring Canadian Vegetation From Space: Results of Recent Studies.

C. S. T. Daughtry, USDA-ARS, Beltsville, MD

Spectral Estimates of Absorbed Radiation and Phytomass in Plant Canopies.

D. W. Deering, NASA-GSFC, Greenbelt, MD

Bare Soil and Plant Canopy Bidirectional Reflectances and Their Relevance in Remote Sensing Applications.

J. Dozier, University of California, Santa Barbara, CA

Seasonal and Interannual Variation of Snow Albedo in the Sierra Nevada, Measured from the Landsat Thematic Mapper.

E. T. Engman, USDA-ARS, Beltsville, MD

Application of Microwave Remote Sensing to Water Resources and Agriculture.

J. H. Everitt and D. E. Escobar, USDA-ARS, Weslaco, TX

Airborne Video Systems for Agricultural Assessment.

S. Goward, University of Maryland, College Park, MD

Primary Production Efficiency - A Concept for Remote Sensing Research.

G. Gutman, NOAA-NESDIS, Washington, D.C.

Vegetation Indices From AVHRR: An Update and Future Prospects.

G. Guyot, INRA, Montfavet, France

Potentials and Limits of Vegetation Indices.

F. Hall, NASA-GSFC, Greenbelt, MD

Remote Sensing of Mass and Energy Exchange Between a Vegetated Surface and the Atmospheric Boundary Layer.

A. R. Huete, University of Arizona, Tucson, AZ and

E. Levine, NASA-GSFC, Greenbelt, MD

Assessment of Biophysical Soil Properties Through Spectral Decomposition Techniques.

R. D. Jackson, USDA-ARS, Phoenix, AZ

Satellites: Future Tools for Farm Management?

J. Townshend, University of Maryland, College Park, MD,

C. J. Tucker, NASA-GSFC, Greenbelt, MD

Monitoring Global Vegetation with NOAA AVHRR Data.

G. W. Petersen, and W. Myers, The Pennsylvania State University, University Park, PA

Role of Geographic Information Systems in Remote Sensing

K. J. Ranson and J. R. Irons, NASA-GSFC, Greenbelt, MD

C. S. T. Daughtry, USDA-ARS, Beltsville, MD

Canopy Albedo from Bidirectional Reflectance.

S. Running, *University of Montana, Missoula, MT and*
H. H. Shugart, *University of Virginia, Charlottesville, VA*
Integration of a Forest Carbon Cycle Model With a
Forest Succession Model, and Applications for
Regional Ecology.

T. Schmugge, *USDA-ARS, Beltsville, MD*
Remotely Sensed Temperature Observations in
HAPEX

B. Seguin, J. P. Lagouarde and M. Savane, *INRA,*
Montfavet, France
The Assessment of Regional Crop Water Condi-
tions from Meteorological Satellites Thermal
Infrared Data.

C. Wiegand, A. J. Richardson and S. J. Maas, *USDA-ARS,*
Weslaco, TX
Vegetation Indices in Crop Assessments.

D. L. Williams, *NASA-GSFC, Greenbelt, MD*
A Comparison of Needle, Branch and Canopy Level
Spectral Reflectance Properties for a Variety of
Conifer Species.

**TRANSPORTATION AND
ACCOMMODATIONS**

The NASA Goddard Space Flight Center is located
northeast of Washington, D.C. on Greenbelt Road near
the intersection of the Capital Beltway and the Baltimore-
Washington Parkway. Three airports serve the Wash-
ington, D.C. area. Baltimore-Washington International
(BWI) is the most convenient and provides direct limou-
sine service to the Greenbelt area.

Sheraton Greenbelt Hotel is offering special confer-
ence rates and will serve as Symposium Headquarters.
This hotel is 1 kilometer from the New Carrollton station
for Metro, which provides rapid, inexpensive access to
Washington, D.C. and to Washington's National Airport.

The registration/reception, and symposium banquet
will take place at the Sheraton Greenbelt Hotel. The
symposium papers will be given at the Building 8 Audi-
torium at NASA-GSFC. A mixer with refreshments will be
held Wednesday night at the Goddard Recreation Center.

The following motels are located within 2 miles of the
auditorium. May is a busy tourist season so you are
advised to make your room reservation directly with the
motel of your choice as soon as possible. The rates
shown are approximate except for Sheraton Greenbelt
Hotel which is firm. All rates are subject to a 15% tax.

Sheraton Greenbelt Hotel
Symposium Headquarters
(Formerly: Howard Johnson Plaza-Hotel)
8500 Annapolis Road, New Carrollton, MD 20784
(Transportation provided to and from Metro)
(301) 459-6700 (Single \$56, Double \$56)

Greenbelt Marriott Hotel
6400 Ivy Lane Greenbelt, MD 20770
(301) 441-3700 (Govt. Rate: Single \$84, Double \$84)

Holiday Inn
7200 Hanover Drive Greenbelt, MD 20770
(301) 982-7000 (Govt. Rate: Single \$72, Double \$72)

Ramada-Capital Beltway
5910 Princess Garden Parkway Lanham, MD 20706
(301) 459-1000 (Govt. Rate: Single \$58, Double \$64)

Red Roof Inn (Rooms Only)
9050 Lanham-Severn Road Lanham, MD 20706
(301) 731-8830 (Single \$44.95, Double \$50.95)

Symposium Chairpersons

John C. Price	Darrel L. Williams
USDA-ARS-RSRL	NASA-GSFC
BARC-West	Code 623
Beltsville, MD 20705	Greenbelt, MD 20771

Previous Symposia in the Series

Virology in Agriculture - 1976
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Animal Reproduction - 1978
Human Nutrition Research - 1979
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Genetic Engineering: Applications to Agriculture - 1982
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Research Instrumentation for the 21st Century - 1986
Biomechanisms Regulating Growth and Development
Keys to Progress - 1987
Biotic Diversity and Germplasm Preservation - Global
Imperatives - 1988
The Rhizosphere and Plant Growth - 1989

REGISTRATION FORM
BELTSVILLE SYMPOSIUM IN AGRICULTURAL RESEARCH - XV
REMOTE SENSING FOR AGRICULTURE
May 16 - 18, 1990

Please Note: Attendance is limited to 350 registrants on a first-come basis.

Name _____

Affiliation _____

Address _____

City _____ State _____ Zip _____

Telephone () _____

Citizenship: USA _____ Other (Specify) _____

If you are **NOT** a U.S. citizen, you are required to submit the enclosed admittance form for foreign nationals.

Registration Fee (entry to all sessions):

Regular (includes proceedings, mixer, banquet)	\$175.00
Late Registration (Postmarked after April 1)	\$225.00
Student (includes proceedings, mixer, banquet)	\$ 75.00
Additional Banquet ticket	\$ 30.00
Additional Mixer ticket	\$ 8.00

Please make check (drawn on U.S. bank) payable to: **Beltsville Symposium XV/FAR-B, Inc.**

Motel Reservations will be made at: (Registration form for Sheraton Greenbelt Hotel enclosed)

I wish to present a poster paper entitled:

Abstract form and instructions enclosed. Deadline for poster abstracts is March 15, 1990. There is no fee for poster abstracts. Poster Session is limited to a first-come basis.

Please return to:

Mrs. M. Blackwell, Conference Secretary
Room 330, Bldg. 001
Beltsville Agricultural Research Center-West
Beltsville, Maryland 20705
Telephone: (301) 344-5055 Fax: (301) 344-5031

Notes: Information on transportation and other pertinent materials is enclosed. Your registration packet containing name tag, program, mixer and banquet ticket(s) and other materials will be available at Registration on Tuesday evening at the Sheraton Greenbelt Hotel or Wednesday morning at the registration desk outside the Building 8 entrance.

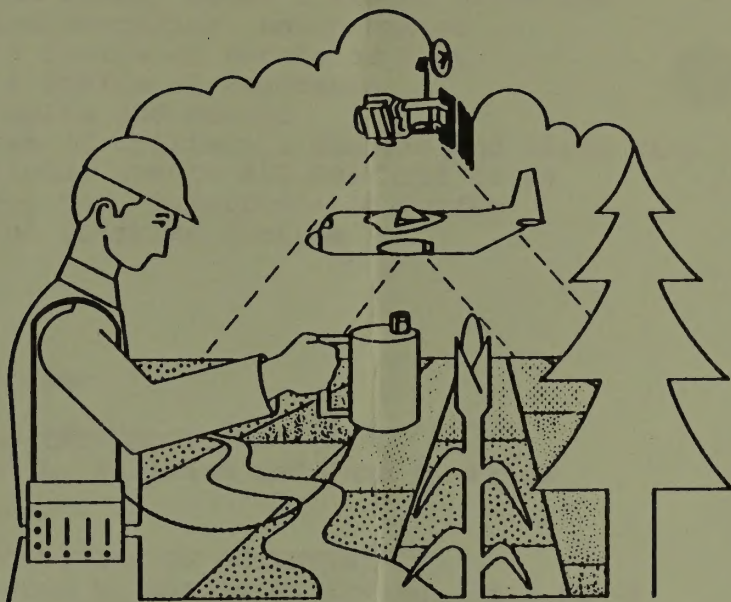
Telephone numbers during symposium hours are:

Emergency: (301) 286-5737

Messages: (301) 286-7065

BANQUET AND EVENING PROGRAM

May 17th, 1990



Beltsville Symposium XV
**REMOTE SENSING
FOR
AGRICULTURE**

PROGRAM

SOCIAL HOUR
(Cash Bar)

6:00-7:00

DINNER

7:00-8:15

Melon with Proscuitto
Spinach Salad, House & French Dressings
Broiled Swordfish, Lemon Butter
Chef's Choice of Potato or Rice
Chef's Choice of Vegetable
Warm Rolls and Butter
Carafes of California Chablis and Blush Wine
Additional carafe \$12.50; half \$6.25
Coffee, Tea, Decaffeinated Coffee
Flaming Cherries Jubilee

Following Dinner:

COMMENTS AND INTRODUCTIONS

Darrel L. Williams and John C. Price

SPECIAL RECOGNITION OF SCIENTIST

Presented by George W. Irving, Jr., FAR-B
Award Recipient 1990 - Dr. Arch Park
For pioneering uniquely valuable
contributions to the development of
the world's first earth sensing
multispectral satellite, now known as
Landsat, which has opened new vistas in
agricultural remote sensing.

BANQUET ADDRESS

The Honorable George E. Brown
Representative from the State of California

SECOND ANNOUNCEMENT

Beltsville Symposium XV

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- F. Hall**, *NASA-GSFC, Greenbelt, MD*
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Between a Vegetated Surface and the Atmospheric
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E. Levine, *NASA-GSFC, Greenbelt, MD*
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Through Spectral Decomposition Techniques.
- R. D. Jackson**, *USDA-ARS, Phoenix, AZ*
Satellites: Future Tools for Farm Management?
- C. O. Justice**, *University of Maryland, College Park, MD, and*
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The Rhizosphere and Plant Growth - 1989

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Agricultural Research Service
Beltsville, Maryland 20705
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FINAL ANNOUNCEMENT

Beltsville Symposium XVI

**PHOTOMORPHOGENESIS
IN PLANTS:
EMERGING STRATEGIES
FOR CROP IMPROVEMENT**

September 22–27, 1991

**University of Maryland University
College
Conference Center**

College Park, Maryland

To be held jointly with the

**1991 European
Photomorphogenesis Symposium**

**CELEBRATING FOUR DECADES OF PROGRESS IN
PHYTOCHROME RESEARCH**

**Sponsored by
Beltsville Area, Agricultural Research Service, USDA**

**with the cooperation of
Friends of Agricultural Research–Beltsville, Inc.**

**and the assistance of
The Maryland Agricultural Experiment Station
and the
National Research Initiative Competitive Grants Program,
Cooperative State Research Service, USDA**

Beltsville Symposium XVI will mark the fortieth anniversary of the beginning of phytochrome research at Beltsville in 1951. It will encompass recent progress in photomorphogenesis research and related, emerging strategies for crop improvement. The symposium will honor early pioneers in phytochrome research. All who are interested in this rapidly advancing research area are invited.

The symposium will be held at the Conference Center of the University of Maryland University College in College Park, Maryland. Visits to the Beltsville Agricultural Research Center and the site of the early phytochrome work will be conducted.

Symposium sessions will consist of both invited talks and poster presentations. Speakers will be invited to contribute manuscripts describing original research from their work, for peer-review and publication in a special proceedings issue of *Photochemistry & Photobiology*.

About 100 poster presentations are planned. Posters will be available for viewing throughout the meeting and specifically scheduled for discussion during Monday and Tuesday evenings. Both oral and poster presentations require the submission of abstracts by August 16, 1991 (postmark). These abstracts will be included in the meeting program. Instructions for the preparation of abstracts and posters will be sent to registrants.

SESSIONS, SPEAKERS, AND SUBJECTS

SUNDAY, September 22

Registration

Evening Reception

MONDAY

1. Reflections on the Early Years of Phytochrome Research

A. A. Piringer, USDA-ARS, Beltsville, MD (retired)

Introduction of and comments by phytochrome pioneers.

2. Phytochrome Function in the Natural Environment

J. J. Casal, Universidad de Buenos Aires, Argentina

Phytochrome and carbon partitioning: Mechanisms and ecological significance.

S. J. Britz, USDA-ARS, Beltsville, MD

Photoregulation of photosynthate partitioning and product quality in crop plants.

M. J. Kasperbauer, USDA-ARS, Florence, SC

Phytochrome regulation of growth and development in field-grown plants.

A. L. Mancinelli, Columbia University, New York, NY

Phytochrome-mediated detection of changes in reflected light.

H. Smith, University of Leicester, England

Ecological functions of the phytochrome family: Clues to a transgenic programme of crop plant improvement.

G. Whitelam, University of Leicester, England

R:FR ratio perception in photomorphogenetic mutants.

D. Koller, The Hebrew University, Israel

Light-driven leaf movements.

- R. Konjevic**, *University of Belgrade, Yugoslavia*
Organic nitrates in the germination of phytochrome-controlled seeds.
- C. L. Ballaré**, *Oregon State Univ. & Univ. of Buenos Aires*
Photomorphogenic processes in the agricultural environment.
- 3. Photoperiodism**
- S. D. O'Neill**, *University of California, Davis, CA*
The photoperiodic control of flowering: Are we any closer to the mechanism?
- P. J. Lumsden**, *Lancashire Polytechnic, Preston, England*
Roles for phytochrome in photoperiodism
- G. F. Deitzer**, *University of Maryland, College Park, MD*
Molecular genetics of floral induction.
- É. Ádám**, *Hungarian Research Centre, Szeged, Hungary*
VLFR induced circadian clock-regulated transcription of the wheat Cab-1 gene in wheat and transgenic tobacco seedlings.
- B. Wehmeyer**, *Universität Freiburg, Germany*
Rhythmic expression of CAB genes in etiolated wheat and transgenic tobacco seedlings.
- Poster Session #1, 7:30–10 pm**

TUESDAY

- 4. Blue Light Photoreception, Phototropism, & UV Photoreception**
- W. R. Briggs**, *Carnegie Inst. of Washington, Stanford, CA*
Early events following blue light perception in pea epicotyls and maize coleoptiles.
- S. M. Assmann**, *Harvard University, Cambridge, MA*
Signal transduction in guard cells: Regulation of stomatal aperture by blue light and lipids.
- M. Wada**, *Tokyo Metropolitan University, Tokyo, Japan*
Is the blue light photoreceptor the only photoreceptor for phototropism?
- E. Lipson**, *Syracuse University, Syracuse, NY*
Signal transduction in *Phycomyces* phototropism.
- K. L. Poff**, *Michigan State University, Lansing, MI*
Adaptation of phototropism: An involvement of phytochrome.
- P. A. Galland**, *Philipps-Universität, Marburg, Germany*
The role of flavins and pterins in the photoreception of *Phycomyces*.
- A. W. Galston**, *Yale University, New Haven, CT*
Interactions of red and blue light in patterns of auxin distribution and phototropic behavior in etiolated peas.
- P. J. Davies**, *Cornell University, Ithaca, NY*
The role of indolacetic acid in mediating phytochrome induced changes in stem elongation.
- M. Kraml**, *University of Erlangen, Germany*
Light adaptation and dark adaptation of *Mougeotia* chloroplast movement.
- B. R. Greenberg**, *University of Waterloo, Ontario, Canada*
UV-B induced photomorphogenesis in *Brassica napus*.

- B. R. Jordan**, *Horticult. Resch. Intl., Littlehampton, England*
The effect of supplementary UV-B radiation on gene expression for chloroplast proteins.
- A. Mattoo**, *USDA-ARS, Beltsville, MD*
Photoregulated phosphorylation targets the D1 protein of Photosystem II for degradation.
5. Phytochrome Mutants and Transgenic Plants
- R. E. Kendrick**, *Agric. Univ., Wageningen, The Netherlands*
Mutants as an aid in assigning function(s) to different phytochromes.
- R. D. Vierstra**, *University of Wisconsin, Madison, WI*
Structural and functional analysis of phytochrome using transgenic plants.
- J. Stockhaus**, *The Rockefeller University, New York, NY*
The analysis of phytochrome functions in transgenic plants.
- J. Chory**, *Salk Institute, San Diego, CA*
Genetic analysis of light signal transduction pathways.
- B. Lercari**, *University of Pisa, Italy*
Photomorphogenic responses to UV radiation in an *aurea* mutant of tomato.
- R. P. Hangarter**, *Ohio State University, Columbus, OH*
Blue light response mutants in *Arabidopsis*.
- Poster Session #2, 7:30–10 pm**

WEDNESDAY

6. Phytochrome regulated gene expression.
- P. H. Quail**, *USDA-ARS, Albany, CA*
Phytochrome-regulated *phyA* gene expression.
- W. F. Thompson**, *North Carolina State University, Raleigh, NC*
Light response mechanisms regulating ferredoxin mRNA accumulation
- R. Oelmüller**, *Botanisches Institut, München, Germany*
Regulation of expression of nuclear-encoded genes for proteins of the photosynthetic apparatus in transgenic *N. tabacum*.
- J. C. Watson**, *University of Maryland, College Park, MD*
Photoregulated expression of protein kinase genes in pea seedlings.
- E. M. Tobin**, *University of California, Los Angeles, CA*
Strategies for understanding phytochrome regulation of transcription.
- A. R. Cashmore**, *Univ. of Pennsylvania, Philadelphia, PA*
Multiple GBF-like transcription factors bind to the G-box sequences of photoregulated plant genes.
- A. Batschauer**, *Universität Freiburg, Freiburg, Germany*
Light regulated gene expression in mustard.
- J. Silverthorne**, *University of California, Santa Cruz, CA*
Phytochrome regulation of gene expression in *Pinus palustris*.
- Excursion (optional). Noon - 10 pm**, to St. Michaels on Maryland's eastern shore; Chesapeake Bay cruise and crab feast.

THURSDAY

7. Light Mediated Signal Transduction

- E. Schäfer**, *Universität Freiburg, Freiburg, Germany*
Approaches to analyse light mediated signal transduction.
- G. Wagner**, *Justus-Liebig-Universität, Giessen, Germany*
Chloroplast orientation in *Mougeotia* with respect to light.
- E. Hartmann**, *Free University, Berlin, Germany*
Phytochrome-mediated signal storage.
- S. K. Sopory**, *Jawaharlal Nehru University, New Delhi, India.*
Signal transduction in phytochrome stimulation of enzymes: Nitrate reductase as a model system.
- R. W. Scheuerlein**, *Freidrich-Alex.-Univ., Erlangen, Germany*
Phytochrome-mediated germination in fern spores as an example for a light-mediated signal-transduction chain.
- S. J. Roux**, *University of Texas, Austin, TX*
Phytochrome regulation of Ca^{+} -stimulated nuclear enzymes.
- H. Schneider-Poetsch**, *University of Köln, Germany*
Phytochrome has a transmitter module. It is related to bacterial sensor proteins.
- T. Lamparter**, *Universität Freiburg, Freiburg, Germany*
The search for phytochrome-binding membrane proteins.
- L. S. Kaufman**, *University of Illinois at Chicago, IL*
Blue-light mediated signal transduction.

8. Phytochrome Structure and Properties

- B. Thomas**, *Horticult. Research Intl., Littlehampton, England*
Phytochrome characterization – some means to an end.
- M. Furuya**, *Frontier Res., RIKEN, Wako City, Saitama, Japan*
Structure and function of diverse phytochrome types and gene-engineered phytochromes.
- L. H. Pratt**, *University of Georgia, Athens, GA*
Three phytochromes and their differential expression.
- A. M. Jones**, *University of North Carolina, Chapel Hill, NC*
Protein-protein interactions in phytochrome.
- P.-S. Song**, *University of Nebraska, Lincoln, NE*
Functional implications of the phytochrome conformations.
- W. Rüdiger**, *Universität Munchen, Germany*
Events in the phytochrome molecule after phototransformation.
- V. A. Sineshchekov**, *Moscow State University, USSR*
A new direction of phytochrome investigation *in vivo*: Fluorescence spectroscopy of the pigment.
- J. C. Lagarias**, *University of California, Davis, CA*
In vitro phytochrome assembly.

9. Opportunities and Future Research Directions

- H. Mohr**, *Universität Freiburg, Freiburg, Germany*
Success and failure in phytochrome research: What can we learn from the past?
- D. Vince-Prue**, *University of Reading, England*
Photoperiodism: prospects and problems.

Symposium Banquet: Speaker - **H. M. Cathey**, Director,
U.S. National Arboretum, USDA-ARS, Washington, D.C.

FRIDAY, September 27

Departure

REGISTRATION FORM

BELTSVILLE SYMPOSIUM XVI PHOTOMORPHOGENESIS IN PLANTS: EMERGING STRATEGIES FOR CROP IMPROVEMENT

September 22-27, 1991

College Park, Maryland

Name _____ Title _____

Affiliation _____

Address _____

City _____ State _____ Zip _____

Phone _____ Fax _____

Registration Fee (incl. proceedings, reception & banquet)

Regular \$175 _____

Late (postmarked after August 16) \$225 _____

Student (graduate or undergraduate) \$75 _____

Additional Banquet ticket \$30 _____

Additional Reception ticket \$25 _____

Excursion (Wed. afternoon-evening) \$48 _____

(not included in registration fee)

Total _____

Please make check (drawn on a U.S. bank) payable to:

Beltsville Symposium XVI / FAR-B, Inc.

Lodging Reservations will be made at: _____

I wish to present a poster entitled: _____

Instructions for the preparation of abstracts and posters will be sent upon the receipt of this form. Deadline for abstracts is **August 16, 1991** (postmark).

Please send copy of form and check to:

Beltsville Symposium XVI

Bldg. 046A, Climate Stress Lab., USDA, ARS

Beltsville Agricultural Research Center

10300 Baltimore Blvd.

Beltsville, Maryland 20705-2350

For more information please contact: Dr. W. VanDerWoude
or Ms. V. Hupfer. Phone: (301) 344-3607. Fax: 344-4626.
Internet: wvanderwoude@asrr.arsusda.gov

TRANSPORTATION AND ACCOMMODATIONS

All formal symposium activities will be held at the:

Conference Center

University of Maryland University College

University Boulevard at Adelphi Road

College Park, MD 20742-1606

(301) 985-7300 (Front Desk - 24 hours)

The Center is 8 miles northeast of the Capitol Building in Washington, DC. Three airports serve the area. Baltimore-Washington International (BWI) is the most convenient and provides direct limousine service to the Beltsville/College Park area. Additional information on local transportation will be sent upon registration.

All necessary facilities, including lodging, dining, and ample parking, are conveniently available at the Center. Please contact the Symposium Office to reserve lodging at the Center. Room rates, including tax, are:

<u>Room Style</u>	<u>Single</u>	<u>Double</u>
Queen (1 double bed)	\$68.25	\$42.00/person
Twin (2 single beds)	\$63.00	\$42.00/person

Motel information is provided primarily for those with cars. Motel reservations should be made directly. Mention that you are attending the USDA, Beltsville Symposium.

<u>Motel</u>	<u>Street #</u>	<u>Phone #</u>	<u>Miles</u>	<u>Single</u>	<u>Double</u>
Quality Inn	7200	864-5820	1.3	\$46	\$52
Best Western	8601	474-2800	1.7	\$68	\$72
Comfort Inn	9020	441-8110	2.1	\$50	\$55
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Super 8	9150	474-0894	2.4	\$52	\$54
Holiday Inn	10000	345-6700	3.5	\$70	\$70

Addresses: (St. #) Baltimore Blvd, College Park, MD 20740
Phone: Area Code 301

"Miles" is distance from the Conference Center.

Daily rates are to the nearest \$, including taxes.

COMMUNICATIONS AT THE SYMPOSIUM

Symposium Information Center (301) 985-7675

(Beginning Sunday, September 22. Will connect with the Front Desk when not attended.)

BELTSVILLE SYMPOSIUM XVI

Program Committee

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Beltsville Agricultural Research Center

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University of Maryland, College Park, MD

Previous Symposia in the Series

Virology in Agriculture – 1976

Biosystematics in Agriculture – 1977

Animal Reproduction – 1978

Human Nutrition Research – 1979

Biological control in Crop Production – 1980

Strategies of Plant Reproduction – 1981

Genetic Engineering: Applications to Agriculture – 1982

Agricultural Chemicals of the Future – 1983

Frontiers of Membrane Research – 1984

Biotechnology for Solving Agricultural Problems – 1985

Research Instrumentation for the 21st Century – 1986

Biomechanisms Regulating Growth and Development:

Keys to Progress – 1987

Biotic Diversity and Germplasm Preservation – Global

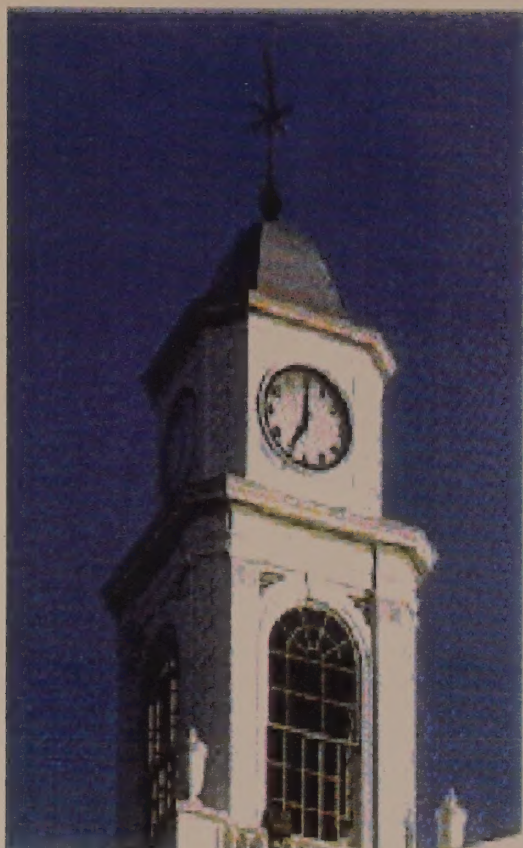
Imperatives – 1988

The Rhizosphere and Plant Growth – 1989

Remote Sensing for Agriculture – 1990

Future Symposium

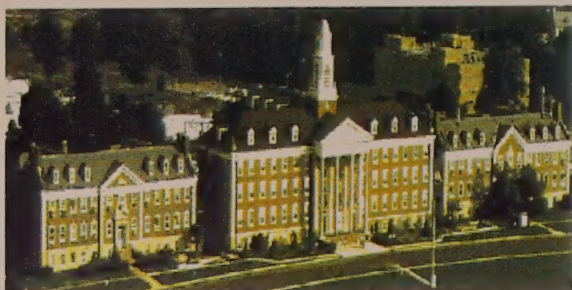
Agricultural Water Quality Priorities – May 6-8, 1992



**FRIENDS OF
AGRICULTURAL
RESEARCH -
BELTSVILLE, INC.**

FRIENDS OF AGRICULTURAL RESEARCH - BELTSVILLE (FAR-B)

FAR-B is a non-profit group dedicated to supporting the research and education programs maintained since 1910 at the Beltsville Agricultural Research Center (BARC).



BARC is the centerpiece of the Agricultural Research Service (ARS), the principal research agency of the U.S. Department of Agriculture (USDA). FAR-B members are USDA alumni and individuals and groups from academia, industry, government, and the public who want to help this world-renowned research center continue its excellence in the agricultural sciences. To accomplish its purpose, FAR-B: (1) disseminates information regarding significant accomplishments and expertise at BARC, (2) helps organize and support the annual Beltsville International Symposium, (3) collects funds to help upgrade equipment and research facilities at BARC, and (4) assists in developing programs of interest to the many who visit the ARS National Visitor Center at Beltsville.

THE BELTSVILLE AREA

The Beltsville Area of ARS includes the Agricultural Research Center (presently composed of 4 institutes), the Human Nutrition Research Center, the nearby U.S. National Arboretum in D.C., and the U.S. Plant Introduction Station at

Glendale, MD. Spread over 7,000 acres at BARC, and 444 acres at the U.S. National Arboretum, the Beltsville Area has experimental pastures, nurseries, orchards, gardens, fields for cultivated crops, forested ecosystems, and soil-treatment plots; plus more than 600 buildings that house the specialized laboratories, offices, and personnel. The mission of the permanent and visiting scientists and post-doctoral fellows is to develop the knowledge and technology required to solve agricultural problems of broad scope and high national priority, and thereby: (1) meet the nutritional needs of the American consumer, (2) sustain a viable food and agricultural economy, and (3) preserve a quality environment and natural resource base. Research in the Beltsville Area contributes to the major ARS objectives of promoting food and fiber production through soil and water conservation, optimizing plant and animal productivity, improving commodity conversion and deliver, bettering human nutrition, and integrating systems of technology that upgrade agricultural endeavors. This research complements that of universities, industry, scientists working at other ARS locations, and researchers worldwide.

VISITORS PROGRAMS



Visitors to facilities in the Beltsville Area have ranged from U.S. Presidents to foreign heads of

State, from scientists to farmers and industrialists, from tourists to school children.



Interest in the Center stems from the high esteem in which this institution is held worldwide. Beauty also attracts visitors . . . for example, the National Arboretum is a favorite for both tourists and local visitors, especially in Spring when the azaleas bloom. Other displays, such as the bonsai collection, draw visitors the year round. Examples of research achievements are on display in the "Log Lodge", a large and noteworthy structure built by the Civilian Conservation Corps during the 1930's. Located in the Log Lodge, the ARS National Visitor Center (tel. 301-504-9403) regularly arranges and conducts tours of laboratories, barns, greenhouses, and fields . . . limited, of course, to occasions and areas that can be opened to the public with minimum interference to research underway.

BELTSVILLE SYMPOSIUM

FAR-B has helped sponsor since 1976, an international symposium which has been held annually at Beltsville. Each has dealt with a topic of importance - one to which Beltsville scientists and their cooperators were or are making major

contributions. Speakers are invited from government, academia, and industry in this country and abroad. Proceedings of each symposium are published and made available to scientists throughout the world.



Members of FAR-B cooperate in organizing and facilitating operation of the symposia. For more information about the current symposium contact: home page: [http:// www.barc.usda.gov/](http://www.barc.usda.gov/) and click on Friends of Agricultural research Beltsville (FARB) and scroll to Beltsville Symposium or send request to address below.

How to become a member of FAR/B

Membership categories:

Personal membership: \$20.00

Patron membership: \$100.00

Sustaining membership: over \$500.00

Associate membership: \$10.00 (non-voting; for USDA employees)

Send a check with your name and address to Friends of Agricultural Research - Beltsville, Inc., P.O. Box 1061, Beltsville, MD 20705-1061.



**Facilities of the
Agricultural Research Service
United States Department of Agriculture
Washington, D.C., and Vicinity**

Global Genetic Resources—Access, Ownership, and Intellectual Property Rights

Agricultural Research Service
U.S. Department of Agriculture
Association of Systematics
Collections

Beltsville, Maryland
May 19–22, 1996



BELTSVILLE SYMPOSIUM XXI

Global Genetic Resources—Access, Ownership, and Intellectual Property Rights

The purpose of this symposium is to explore issues related to ownership of and access to genetic resources and biological specimens as they affect the ability of scientists to do their job of providing knowledge to benefit the people of the world. While scientists desire free, international distribution of germplasm and scientific information on biodiversity, current forces and trends are leading away from this position. A mutually beneficial compromise is needed. This meeting will explore these possibilities.

Program

[Saturday Afternoon, May 18

Sunday Morning including Lunch, May 19

ASC Pre-Symposium Workshop on Government Relations for Institutional Leaders.]

Sunday Afternoon, May 19

ASC business meeting (open to all)

Sunday Evening, May 19

Opening Reception and Poster Session,
6:00-9:00 PM, Holiday Inn Ballroom.

1 Monday Morning, May 20

Use of Genetic Resources: The Problem

Welcome—K.D. Murrell, Director, Beltsville Area

Keynote Address: Biodiversity and the Equitable Use of the World's Genetic Resources. Peter Day, Cook College-Rutgers, New Brunswick, New Jersey

Sustainable Use of Little-Known Biological Resources: Policy Choices for Governments. Speaker TBA

North vs South Politics, or Arguments for Equity. Daniel Witmeyer, Alexandria, VA

Summary of Legal Issues. Laws, International Treaties Including the Biodiversity Treaty. Bill Lesser, Cornell University, Ithaca, NY

The Biodiversity Convention and the Flow of Scientific Information. John Barton, Stanford University, Stanford, CA

2 Monday Afternoon, May 20

Value of Specimen-Based Research to the Global Community

Opening Talk: How Can Scientists Maximize the Worth of Biological Resources to Society? Quentin Wheeler, Cornell University, Ithaca, NY

Case studies:

Introduced Parasites and Emerging Diseases. Eric Hoberg, Biosystematic and National Parasite Collection Unit, ARS, Beltsville, MD

Developing Fungi as Biocontrol Agents. Amy Rossman, U.S. National Fungus Collections, ARS, Beltsville, MD

Germplasm and Agricultural Products. Henry Shands, Germplasm Resources Leader, ARS, Beltsville, MD

Insects. Natalia Vandenberg, Systematic Entomology Laboratory, ARS, Beltsville, MD

Microbial Products. Jennie Hunter-Cevera, Center for Environmental Biotechnology, Berkeley, CA

Vascular Plants. Vicki Funk, Smithsonian Institution, Washington, DC

Horticulture: Its Economic Undervaluing in Society. Thomas Elias, National Arboretum, Washington, DC

continued on Tuesday, May 21

Plant Collecting. Maxine Thompson, Oregon State University, Corvallis.

Tissue Collection and Exchange. Fred Sheldon, Louisiana State University, Baton Rouge

Monday Evening, May 20

Media Panel Discussion. Paul Raeburn, Science Editor, Associated Press, New York, NY

3 Tuesday Morning, May 21

Models for Equitable Use of Genetic Resources

The Canadian Viewpoint. Jacques Surprenaut, CLBRR, Ottawa, Ontario

Harvesting Wild, Edible, Mycorrhizal Fungi in Oaxaca, Mexico. Ignacio Chapela, University of California, Berkeley

Bioprospecting Using African Genetic Resources. Maurice Iwu, Silver Spring, MD

Parasitic Diseases in the Arctic: Insights from the Inuit. Robert Rausch, University of Washington, Seattle

Marine Biodiversity Prospecting. Shirley Pomponi, Harbor Branch Oceanographic Institute, Ft. Pierce, FL

4 Tuesday Afternoon, May 21

Potential Solutions for Equitable Use of Genetic Resources

Opening Talk: The International Germplasm Collections Under the Rule of the Biodiversity Convention. Wolfgang Siebeck, CGIAR, Washington, DC, and Jan Engels, IPGRI, Rome.

Biodiversity Prospecting and Models for Collections Resources: NSF/USAID/NIH Model. Barbara Timmermann, University of Arizona, Tucson

Material Transfer Agreements. Marie Ferrar, Office of Technology Transfer, National Institutes of Health, Bethesda, MD

Equitable Use of Biodiversity in Mexico Through the Sustainable Development of Plants and Plants Products. Oscar Dorado Rameriz, Universidad Autonoma de Morelos, Cuernavaca, Mexico

Tuesday Evening. Banquet at Patuxent Wildlife Refuge Visitors Center, Laurel, MD

Wednesday Morning, May 22.

Potential Solutions for Equitable Use of Genetic Resources (continued)

GEF and Biodiversity Resource Information. Mario Ramos, Global Environmental Facility, World Bank, Washington, DC

Model Biodiversity Legislation as a Tool for Promoting Conservation and Sustainable Use of Biodiversity. Walt Reid, World Resources Institute, Washington, DC

Poster Presentation

If you wish to present a poster at the Symposium, please provide the information below by March 1, 1996. Posters will be displayed in the Holiday Inn, College Park during evening social hours and noon breaks.

Title:

Authors:

General Information

The Twenty-First Beltsville Symposium and 1996 ASC Annual Meeting will take place in the auditorium of Building 003, Beltsville Agricultural Research Center, 10300 Baltimore Ave., Beltsville, MD, May 19-22, 1996.

Informal receptions and poster sessions will be held both on Sunday evening, May 19 and on Monday evening, May 20, at the Holiday Inn, College Park, MD. Contributed poster papers are welcome; titles must be submitted via the attached registration form by March 1, 1996.

A block of rooms has been reserved at the Holiday Inn, 10000 Baltimore Blvd., College Park, MD 20740, (tel. 800-872-5564, 301-345-6700; fax: 301-441-4923). For the special rate of \$69 per night including breakfast hotel reservations must be made by May 1, 1996.

The Co-Chairs of the Symposium are **Amy Y. Rossman**, Systematic Botany and Mycology Laboratory, Rm. 304, B011A, 10300 Baltimore Ave., Beltsville, MD 20705, 301-504-5364, FAX (301) 504-5810, email: amy@fungi.ars-grin.gov; **Thomas Elias**, National Arboretum, Washington, DC, 202-245-4539, FAX 202-245-4575; and **K. Elaine Hoagland**, Association of Systematics Collections, 730 11th St. 2nd Floor, Washington, DC 20001, 202-347-2850, FAX 202-347-0072, email: elaine@ascoll.org. For further information, contact any of the Co-Chairs.



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December 1995

9-9-97

Beltsville
Symposium
May 1998

**Fresh
Fruits
and
Vegetables**

**Quality
and
Food Safety**



First Announcement

Beltsville Symposium XXIII

Fresh Fruits and Vegetables: Quality and Food Safety

May 3-6, 1998

Topics and Session Moderators

- ◆ **Fresh Fruits and Vegetables—Patterns of Consumption**
Chien Yi Wang, ARS, Beltsville, MD
- ◆ **What Is Quality and How Is it Measured?**
Miklos Faust, ARS, Beltsville, MD
- ◆ **Preharvest Factors Affecting Quality**
William Bramlage, Univ. of Massachusetts
- ◆ **Postharvest Factors Affecting Quality**
Adel Kader, Univ. of California, Davis
- ◆ **Current Issues in Food Safety**
William Romig, EPL Technologies, West Conshohocken, PA
- ◆ **Current Issues in Fresh-cut Produce**
Edith Garrett, International Fresh-cut Produce Association, Alexandria, VA



This symposium is for researchers, producers, users, consultants, and decision makers interested in high quality fresh fruits and vegetables. Quality and safety are of paramount importance to consumers, who want fresh produce that is safe (free from contamination by human pathogens), attractive, fragrant, flavorful, of proper texture, residue-free, and highly nutritious. In addition, there is increasing demand by both consumers and the food service industry for fruits and vegetables that are packaged and sold in a pre-cut form ("fresh-cut"). However, little is known about how the quality and nutrient content of these fresh-cut fruits and vegetables change during storage and marketing. This Symposium will address these issues.

Internationally renowned experts will discuss recent research, technical advances, and the next generation of challenges and opportunities in postharvest quality maintenance and measurement. Poster sessions will complement the invited presentations.

Organized by

Kenneth Gross and Chien Yi Wang
USDA, ARS, Plant Sciences Institute
Horticultural Crops Quality Laboratory
Agricultural Research Center
Beltsville, MD 20705-2350
Phone: 301-504-6128
Fax: 301-504-5107
e-mail: kgross@asrr.arsusda.gov

Sponsored by

Friends of Agricultural Research—
Beltsville, Inc.
Beltsville Agricultural Research Center
ARS, USDA

Ms. Kendra Jenkins, Symposium Secretary
Horticultural Crops Quality Laboratory
Bldg. 002, Rm. 117, BARC-West
10300 Baltimore Avenue
Beltsville, MD 20705-2350
USA

Phone: 301-504-6128
Fax: 301-504-5107
e-mail: kgross@asrr.arsusda.gov

Preliminary Registration Form

Please send further announcements to

Family name: _____

First name: _____

Organization: _____

Street address: _____

City: _____

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Phone: _____

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e-mail: _____

☐ I am interested in exhibiting a poster

Beltsville Symposium 1998

Fresh Fruits and Vegetables



Quality and Food Safety

Final Announcement

Beltsville Symposium

May 1998

Fresh Fruits and Vegetables

Quality and Food Safety



Beltsville Symposium XXIII, *Fresh Fruits and Vegetables - Quality and Food Safety*, is for researchers, producers, users, consultants, and decision makers interested in high quality fresh fruits and vegetables. Quality and safety are of paramount importance to consumers, who want fresh produce that is safe (free of human pathogens), attractive, fragrant, flavorful, of proper texture, residue-free, and nutritious. In addition, there is increasing demand by both consumers and the food service industry for fruits and vegetables that are packaged and sold in pre-cut form ("fresh-cut"). However, little is known about how the quality and nutrient content of these fresh-cut fruits and vegetables change during storage and marketing. This Symposium will address these issues. Internationally renowned experts will discuss recent research, technical advances, and the next generation of challenges and opportunities in postharvest quality maintenance and measurement. Poster sessions will complement the invited presentations.

Sunday Afternoon, May 3

Registration

2:00-5:00 PM. Holiday Inn. College Park

Evening — Opening Reception

6:00-9:00 PM, Holiday Inn Ballroom

Monday Morning, May 4

① Opening Session

Moderator: Ken Gross, Hort. Crops Quality Lab.,
USDA-ARS, Beltsville, MD

Welcome

8:30 AM Phyllis Johnson, Beltsville Area Director,
USDA-ARS, Beltsville, MD

Introductory Remarks

8:35 AM (To be announced)

FAR-B Distinguished Scientist Award

8:50 AM Phillip C. Kearney, President, Friends of
Agricultural Research - Beltsville, MD

② Overview

Moderator: Chien Yi Wang, Hort. Crops Quality Lab.,
USDA-ARS, Beltsville, MD

9:00 AM Introduction

Importance and Consumption Patterns of Fruits and Vegetables

9:10 AM Alanna Moshfegh, Food Surveys Research
Group, USDA-ARS, Riverdale, MD

9:40 AM **Break**

③ Quality

Moderator: Miklos Faust, Fruit Laboratory,
USDA-ARS, Beltsville, MD

10:10 AM Introduction

What is Quality?

10:20 AM Robert L. Shewfelt, University of
Georgia, Athens, GA

Sensory Analysis of Quality

10:50 AM Rolf Kuchenbuch
Institute for Vegetable & Ornamental Crops,
Grossbeeren, Germany

Quality Measurement

11:20 AM Judith A. Abbott, Hort. Crops Quality Lab.,
USDA-ARS, Beltsville, MD

Discussion, Summary, and Conclusion

11:50 AM

12:00 noon **Lunch**

Monday Afternoon, May 4

④ *Preharvest Factors Affecting Quality*

Moderator: William Bramlage, Univ. of Massachusetts,
Amherst, MA

1:00 PM Introduction

Preharvest Factors Affecting Flavor

1:10 PM James P. Mattheis, USDA-ARS,
Wenatchee, WA

Preharvest Factors Affecting Appearance

1:40 PM Stanley J. Kays, University of Georgia,
Athens, GA

Preharvest Factors Affecting Texture

2:10 PM Carl Sams, University of Tennessee,
Knoxville, TN

2:40 PM Break

Preharvest Factors Affecting Nutrition

3:10 PM Leslie A. Weston, University of Kentucky,
Lexington, KY

Preharvest Factors Affecting Physiological Disorders and Diseases

3:40 PM Ian B. Ferguson, Hort. and Food Research,
Institute, Auckland, New Zealand

Discussion, Summary and Conclusion

4:10 PM

Monday Evening, May 4

① Poster Session One

7:30-8:30 PM Holiday Inn Ballroom

Tuesday Morning, May 5

⑤ *Postharvest Factors Affecting Quality*

Moderator: Adel A. Kader, University of California,
Davis, CA

8:30 AM Introduction

Effect of Temperature and Relative Humidity on Quality

8:40 AM Robert E. Paull, University of Hawaii,
Honolulu, HI

Effect of Ethylene on Quality

9:10 AM Mikal E. Saltveit, University of California,
Davis, CA

Effect of Atmospheric Composition on Quality

9:40 AM Randolph Beaudry, Michigan State Univ.,
East Lansing, MI

10:10 AM **Break**

Postharvest IPM for Decay Control

10:40 AM Joseph L. Smilanick, USDA-ARS,
Fresno, CA

Postharvest IPM for Insect Control

11:10 AM Harvey T. Chan, USDA-ARS,
Hilo, HI

Discussion, Summary, and Conclusion

11:40 AM

12:00 noon **Lunch**

Tuesday Afternoon, May 5

Tour of the Beltsville Agricultural Research Center

1:30 PM

Tuesday Evening, May 5

② Poster Session Two

7:30 - 8:30 PM Holiday Inn Ballroom

Wednesday Morning, May 6

⑥ Current Issues in Food Safety

Moderator: William R. Romig, EPL Technologies,
Philadelphia, PA

8:30 AM **Introduction**

Industry Perspective

8:40 AM Margaret Barth, Redi-Cut Foods,
Franklin Park, IL

Incidence, Contributing Factors, and Control of Bacterial Pathogens in Produce

9:10 AM Robert Brackett, University of Georgia,
Griffin, GA

Incidence, Contributing Factors, and Control of Parasites and Viruses in Produce

9:40 AM Dean Cliver, University of California,
Davis, CA

10:10 AM **Break**

Impact of Postprocess Packaging and Handling on Microbial Populations

10:40 AM Devon Zagory, Devon Zagory Associates,
Davis, CA

Monitoring and Control of Microbiological Hazards: HACCP Real Time Assays

11:10 AM Tom Hankinson, Pure Produce, Inc.,
Worcester, MA

Discussion, Summary, and Conclusion

11:40 AM

12:00 noon **Lunch**

Wednesday Afternoon, May 6

⑦ Current Issues in Fresh-cut Produce

Moderator: Edith H. Garrett, International Fresh-cut
Produce Association, Alexandria, VA

1:00 PM **Introduction**

Finished Product Quality

1:10 PM Alley E. Watada, Hort. Crops Quality Lab.,
USDA-ARS, Beltsville, MD

Product Development Issues

1:40 PM Manny Costa, Costa Fruit & Produce Co.,
Charlestown, MA

Quality Issues During Fresh-cut Processing

2:10 PM Brian Zomorodi, Ready Pac Produce,
Irwindale, CA

2:40 PM **Break**

Physiology of Fresh-cut Produce

3:10 PM Jeffrey K. Brecht, University of Florida,
Gainesville, FL

Packaging Issues and Temperature Control

3:40 PM Alan Hathcox, Cryovac, Duncan, SC

Discussion, Summary, and Conclusion

4:10 PM

Poster Presentations

If you wish to present a poster on results from research, case studies, or demonstrations at the Symposium, please provide the information below as soon as possible, but no later than February 1, 1998. Due to limited space, poster authors will be notified of acceptance by March 15, 1998. Posters will be displayed in the Holiday Inn, College Park, during the evening poster sessions on Monday and Tuesday.

Prospective Poster Presenters: please provide the following information: title (in caps), authors and affiliations, and abstract in 12 point typeface within 6½" by 9" space on hard copy and IBM-compatible disk format. Also indicate the operating system and word processing program used. Please send the Abstract and disk to the Symposium Secretary.

General Information

The Beltsville Symposium XXIII will take place in the auditorium of Building 003, Beltsville Agricultural Research Center, 10300 Baltimore Avenue, Beltsville, Maryland, May 3-6, 1998.

An opening informal reception (Sunday, May 3) and poster sessions (Monday and Tuesday evenings, May 4 & 5) will be held at the Holiday Inn, College Park, MD. The Holiday Inn at College Park is within short walking distance of the meeting site. Attendees requiring special assistance should contact the Symposium Secretary.

A block of rooms has been reserved at the Holiday Inn, 10000 Baltimore Avenue, College Park, MD 20740, at a special rate of \$84 per night including breakfast. Reservations should be made by April 10, 1998 directly with the Holiday Inn. Phone: 800-872-5564 or 301-345-6700; Fax: 301-441-4923

The ARS Beltsville co-chairs of the symposium are Kenneth C. Gross (E-mail: kgross@asrr.arsusda.gov) and Chien Yi Wang (E-mail: cwang@asrr.arsusda.gov), Horticultural Crops Quality Lab.; phone: 301-504-6128, Fax: 301-504-5107). For further information, contact either of the co-chairs.

For questions on abstracts, contact John R. Stommel, Vegetable Laboratory, phone: 301-504-5583, Fax: 301-504-5555, E-mail: jstommel@asrr.arsusda.gov or Robert A. Saftner, Horticultural Crops Quality Lab.; e-mail:rsaftner@asrr.arsusda.gov

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To file a complaint, write to the Secretary of Agriculture, U.S. Department of Agriculture, Washington, D.C. 20250 or call 202-720-7327 (voice) or 202-720-1127 (TDD).

Registration Information

Registration Fees:

_____ \$300 before March 1, 1998, includes Symposium meetings, published proceedings, lunches, and evening receptions
_____ \$350 after March 1, 1998, same as above
_____ \$150 student registration, same as above
_____ \$ 50 spouse registration, includes reception
_____ \$125 one day registration
Mon _____ Tues _____ Wed _____
_____ Total

Payment: Make checks payable to FAR-B, Inc. Acceptable payment is a check drawn on a U.S. bank or money order in U.S. currency. **To register, send the following information with payment to:**

Beltsville Symposium XXIII
ATTN: Kendra Jenkins, Symposium Secretary
10300 Baltimore Avenue
Bldg. 002, Rm. 117
Beltsville, MD 20705-2350
Ph. 301-504-6128; Fax. 301-504-5107

Dr. _____ Ms. _____ Mr. _____ Other _____

Name _____

Name for nametag _____

Affiliation _____

Address _____

Telephone _____

FAX _____

E-mail _____

Horticultural Crops Quality Laboratory
10300 Baltimore Avenue
Bldg. 002, Room 117, BARC-WEST
Beltsville, MD 20705-2350

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First Announcement

BELTSVILLE SYMPOSIUM XXIV
SEPTEMBER 10-12, 2000

HEALTHY ANIMALS 2000

<http://www.barc.usda.gov/fmod/symposium/>



Sponsored by Friends of Agriculture Research - Beltsville, Inc.

Beltsville Symposium XXIV, *Healthy Animals 2000*, is designed for scientists, producers, commodity clients, consultants and managers interested in livestock and poultry health and health-related issues. The promise that biotechnology can provide safe, healthy, productive and nutritious food animals in the new century will be realized through the definition of a healthy animal from a variety of different public and private perspectives. The challenges to animal health and food safety will continue to come from the areas of emerging infectious disease, zoonotic agents, animal stress, and antibiotic resistance, and new concerns about bio-terrorism. Safeguarding animal health will be a product of genomics and genetic selection, the use of probiotics, competitive exclusion products, vaccines and immune-modulators, and integrated and organic management systems. Documentation of food safety and quality will be an important factor in the production and distribution of food animal products worldwide.

This Symposium will provide an opportunity to hear and communicate with a collection of internationally recognized academic, government and industry experts that will present information on the topics of defining healthy animals, food safety, stress and disease, safeguarding animal health and documentation of animal health and food safety. Poster sessions will complement the invited presentations and will be part of a Symposium Proceedings published as a special supplement in *Reviews in Animal Health*.

PROGRAM AND SESSIONS:

SUNDAY (September 10)

Session A - Defining Healthy Animals

Industry Perspective - **Beth Lautner**, National Pork Producers Council, Vice President,
Science & Technology

Regulatory Perspective - **Alfonso Torres**, USDA, APHIS, Director, Veterinary Services

Consumer Perspective - **Caroline Smith-DeWaal**, Center for Science in the Public Interest

Scientific Perspective - **William Wagner**, National Program Leader, Veterinary

Microbiology and Pathology, USDA, CSREES

Animal Welfare/Rights Perspective - **Temple Grandin**, Associate Professor, Animal Science,
Colorado State University

International Perspective - **Alex Thiermann**, USDA, APHIS, Senior Trade Coordinator,
International Services

MONDAY (September 11)

Session B - Stress and Disease

Animal Nutrition and Management - 2 speakers – 1) **Kirk Klasing**, Professor, Department of
Animal Science, University of California, Davis, 2) **Julie Morrow-Tesch**, USDA, ARS,
Research Leader, LIRU

Emerging Infectious Disease - 1) **Corrie Brown**, Professor and Head, Pathology Department,
College of Veterinary Medicine, University of Georgia, 2) **David Swayne**, USDA, ARS,
Research Leader, SEPRL, 2) **J.P. Dubey**, USDA, ARS, BARC, Microbiologist PBEL

Session C - Food Safety

Protecting Animals from Bio-terrorism - **Barry Erlick**, USDA, ARS, Special Programs

Zoonotic Diseases – 1) **Dan Colley**, CDC, Director, Parasitic Diseases Section; 2) **Peter
Mason**, USDA, ARS, PIADC, Research Leader; 3) **Mitchell Palmer**, USDA, ARS, NADC,
Zoonotic Diseases Laboratory.

Antibiotic Resistance - **David White**, FDA, Center for Veterinary Medicine, Office of
Research "Characterization of antibacterial resistance mechanisms"

TUESDAY (September 12)

Session D - Safeguarding Health I

Genomics and Genetic Selection - 2 speakers - TBA

Probiotics and Competitive Exclusion Products - **David Nisbit**, USDA, ARS, Microbiologist
FFSRU

Vaccines and Immunomodulation - 1) **Ron Schultz** Chairman, Department of Pathobiological
Sciences, University of Wisconsin, 2) **Frank Blecha**, Head, Department Anatomy and
Physiology, College of Veterinary Medicine, Kansas State University

Session E - Safeguarding Health II

Integrated Management Systems - **Louis Gasbarre**, USDA, ARS, BARC, Immunologist IDRL

Organic Management Systems - **Keith Boone**, Manager, Horizon Organic Dairies

Session F - Documenting Animal Health and Food Safety

HACCP on the Farm/Certifying Food Safety - 1 speaker- TBA

Certifying Food Quality/Safety to the Consumer - 1 speaker - TBA

Protecting against Emerging Diseases in the Food Supply -1 speaker - TBA

Poster Presentations

Posters containing experimental data and demonstration material will be displayed in the Holiday Inn, College Park, during an evening session on Sunday, September 10. Those interested in presenting a poster should provide a title, authors and affiliations along with an abstract in 12 point typeface as a single paragraph of no more than 2,300 characters (including spaces and punctuation) on hard copy and IBM-compatible disk format (indicate the operating system and word processing program used - disks will not be returned). Please send the Abstract and disk to the Symposium Secretary (Judy Sirk) no later than June 1, 2000. Space is limited and authors will be notified of acceptance for presentation by July 1, 2000. Dimensions of the poster presentation should not exceed a format of 36" X 48". The lettering for the heading with title, authors, and affiliation should be at least 1" (72 points) high. A copy of the abstract, set in large type, should be posted in the upper left-hand corner of the poster. Abstracts will be included in the published proceedings which will be part of a special issue of *Reviews in Animal Health*.

General Information:

The Beltsville Symposium XXIV will take place in the auditorium of Building 003, Beltsville Agricultural Research Center (<http://www.barc.usda.gov>) 10300 Baltimore Avenue, Beltsville, Maryland, September 10 through 12, 2000. An opening informal reception and poster session (Sunday, September 10) will be held at the Holiday Inn, College Park, MD. The Holiday Inn at College Park is within short walking distance of the meeting site. Attendees requiring special assistance should contact the Symposium Secretary. A block of rooms has been reserved at the Holiday Inn, 10000 Baltimore Avenue, College Park MD 20740, at a special rate of \$99 per night including breakfast. Reservations should be made by August 10, 2000, directly with the Holiday Inn. (Telephone 1-800-HOLIDAY or 301-345-6700 or by Fax 301-982-4361).

A special bus tour of the Beltsville Agricultural Research Center will be available for registered participants and accompanying persons between 9:00 - 11:00 a.m. on Wednesday, September 13. Reservations are required and can be made at the symposium site or by contacting John Kucharski on (301) 504-9403 or email kucharsk@asrr.arsusda.gov.

The Beltsville Symposium XXIV co-chairs are Louis Gasbarre (lgasbarr@lpsi.barc.usda.gov) and Joseph Urban (jurban@lpsi.barc.usda.gov) telephone numbers (301) 504-8509 and (301) 504-8765, respectively, and fax (301) 504-5306. For further information, please contact either of the co-chairs or check the website <http://www.barc.usda.gov/fmod/symposium/>. For information on abstracts, contact Joseph Urban.

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REGISTRATION INFORMATION:

Beltsville Symposium XXIV Healthy Animals 2000 September 10-12, 2000

Fees:

_____ \$350 before July 1, 2000, includes Symposium meetings,
published proceedings, lunches and evening reception.
_____ \$400 after July 1, 2000
_____ \$150 student registration
_____ \$ 50 accompanying person registration includes reception.
_____ Total

Payment: Make checks payable to FAR-B, Inc. Acceptable payment is a check drawn on a U.S. bank or money order in U.S. currency. To register, send this completed page with payment to:

Beltsville Symposium 2000
Attn: Judy Sirk, Symposium Secretary
Bldg 1040 Rm 105
BARC-East
Beltsville, Maryland 20705-2350
Telephone: (301) 504-8200
Fax: (301) 504-5306

Dr. _____ Ms. _____ Mr. _____ Other _____

Name _____

Name for nametag _____

Affiliation _____

Address _____

Telephone _____

Fax _____

Email _____

3rd Annual BA - UMD
Fall Symposium 2014

Climate Change
Food and Environmental Security



United States Department of Agriculture

Agricultural Research Service



UNIVERSITY OF
MARYLAND

**Third Annual BA-UMD Symposium:
Climate Change: Food and Environmental Security**

Thursday, January 23, 2014

National Agricultural Library (Abraham Lincoln Building)
10301 Baltimore Avenue
Beltsville, MD 20705-2351

8:15 - 9:00	Registration and poster set-up, Continental breakfast
9:00 - 9:10	Introductory Comments Dr. Joseph Spence , Director USDA-ARS, Beltsville Area Research Center
9:10 - 9:20	Dr. Shirmohammadi to introduce Dr. Cheng-I Wei , Dean of Agriculture University of Maryland
9:20 - 9:25	Dr. Lewis Ziska will introduce Dr. Charles Walthall
9:25 - 10:10	Keynote Speaker: Dr. Charles Walthall National Program Leader for the USDA - ARS Climate Change, Soils and Air Quality Research Program <i>Overview of ARS research on climate change</i>
10:10 - 10:25	Questions and Answers
10:25 - 10:30	Dr. Shirmohammadi to introduce Dr. Donald Boesch
10:30 - 11:15	Dr. Donald Boesch President of the University of Maryland Center for Environmental Science <i>Adapting to climate change for natural resources, food and fiber</i>
11:15 - 11:30	Questions and Answers
11:30 - 11:40	Bob MacDonald <i>ARS & UMD funding opportunities</i>
11:40-11:50	Dr. Lewis Ziska Jointly funded project <i>Climate Change and ragweed pollen</i>
11:50 - 1:15	Lunch and poster session

1:15 - 2:15	Dr. Adel Shirmohammadi , Professor, Associate Dean for Research and Associate Director of Maryland Ag. Experiment Station, University of Maryland <i>Water Resources</i>
2:15 - 3:15	Dr. Dennis Timlin , Research Soil Scientist Crop Systems & Global Change Laboratory Beltsville Agricultural Research Center <i>Biogeochemistry and Mitigation</i>
3:15 - 4:15	Dr. James Bunce <i>Production Systems and Modeling</i>

The goals of the Annual Trends in Agriculture Fall Symposium series, sponsored jointly by Beltsville Area (BA) Agricultural Research Service of the USDA and the University of Maryland (UMD) are i) to provide a forum for discussions of current and future trends in agriculture, and how trends may impact scientific research, agriculture, the environment, and society and ii) to foster collaboration between UMD and BA. The Symposium will host internationally recognized speakers and bring together regional scientists, students, policy makers, and other interested parties for an exciting look at current and emerging issues in agriculture. The symposium this year will also include presentations from the grants office of the University of Maryland with an emphasis on developing joint proposals.

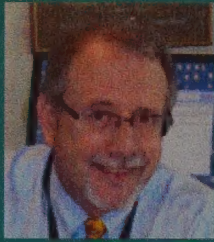
Sponsors

1. Beltsville Area, USDA-ARS (Area Director, Dr. Joseph Spence)
2. The College of Agriculture and Natural Resources, UMD (Dean, Dr. Cheng-I Wei)
3. Friends of Agriculture Research - Beltsville (President, James D. Anderson)
<http://www.ars.usda.gov/Aboutus/docs.htm?docid=9914>
4. TEDCO, Technology Development Corporation

Organizing Committee

Co-chairs: Adel Shirmohammadi, UMD; Lewis Ziska, ARS.

Committee Members: Daniel Strickman, ARS; Dennis Timlin, ARS;
Hubert Montas, UMD; James Bunce, ARS; Jim Poulos, ARS; Jude Maul, ARS;
Lewis Ziska, ARS; Paul Leisnham, UMD; Roger Lawson, retired ARS;
Vicky Carrasco, UMD; Vikki Chanse, UMD.



Overview of ARS research on climate change

Dr. Charles Walthall

National Program Leader for the United States Department of Agriculture, Agricultural Research Service (ARS), Climate Change, Soils and Air Quality Research Program

Dr. Charles Walthall is the National Program Leader for the United States Department of Agriculture Agricultural Research Service (ARS) Climate Change, Soils and Air Quality Research Program. He also oversees ARS remote sensing and geospatial research, plant and environmental process modeling research and development of data management systems for ARS natural resources projects.

Dr. Walthall was introduced to climate change science as a graduate student during 1983, and has interacted with the climate research communities throughout his career. He is the lead author of the first USDA Climate Change Science Plan, the Climate Change and Agriculture: Effects and Adaptation document for the National Climate Assessment, the ARS Climate Change, Soils and Emissions National Program Action Plan, and contributed climate change and soils sections to the USDA Research Economics and Education Strategic Plan. He was also lead author for the agriculture, forestry, and land degradation sections of the first Strategic Plan for the US Integrated Earth Observation System and was invited to participate in the recent US Civil Earth Observations Assessment. He provided guidance for the USDA Climate Change Agency Adaptation Plans structure, co-developed the international Global Research Alliance (GRA) on greenhouse gas reductions agriculture Croplands Research Group, and is currently on the USDA

Climate Change Hubs development team. He serves on interagency working groups on climate change, earth observations, air quality, and soils, and is frequently invited to speak on climate change topics by domestic and international organizations.

Dr. Walthall has a BS in Geography from the University of Maryland; an MS in Forest Science with a specialization in remote sensing from Texas A&M; and a PhD in Agricultural Meteorology and Climatology with a specialization in remote sensing from the University of Nebraska. Prior to joining the ARS Office of National Programs during 2005, Dr. Walthall conducted research to develop remote sensing technologies for urbanized area change detection, rangeland ecology, forestry, agriculture, and land-surface climatology. The research was conducted in the US, Canada, Africa and Russia and involved laboratory and field measurements, modeling, and hardware and software development that contributed to aircraft and satellite sensor systems. Dr. Walthall is ranked among the top 100 authors cited in the remote sensing literature. Prior to joining USDA-ARS in 1994, Dr. Walthall worked with NASA, the University of Maryland and the World Bank.



***Adapting to climate change for natural resources,
food and fiber***

Dr. Donald Boesch

President of the University of Maryland Center for
Environmental Science

Dr. Boesch is a Professor in and President of the University of Maryland Center for Environmental Science and also serves as Vice Chancellor for Environmental Sustainability for the University System of Maryland. He earned his BS from Tulane University and PhD from the College of William and Mary and held faculty positions in Virginia and Louisiana before coming to Maryland in 1990.

An oceanographer who has conducted research on coastal and continental shelf ecosystems through the United States and in China and Australia, Dr. Boesch has published two books and more than 90 papers. Don has served on numerous national scientific advisory boards and committees and is also a member of the Maryland Governor's Chesapeake Bay Cabinet. In recent years, he has worked to understand the potential impacts of climate change and how to adapt to them. He is a contributing author to the 2009 report *Global Climate Change Impacts in the United States* and the National Academies' *America's Climate Choices* report. Don chairs the Scientific and Technical Work Group of the Maryland Commission on Climate Change and led the production of its climate impacts assessment and new projections of sea-level rise for Maryland.

Abstract

The science is compelling that climate change is occurring, is caused predominantly by human activities, and poses serious risks to humans and the biosphere that support us. Agriculture is a significant contributor to anthropogenic climate change, responsible directly for 13% of greenhouse gas emissions and contributing additionally through land-use changes associated with food and fiber production. Additionally, agricultural security is threatened by warming, reduced or variable soil moisture, and extreme events associated with climate change at the very same time that there is growing demand for food and fiber to support the growing world population and improve lives. The twin challenge for agriculture, then, is both to contribute to efforts to reduce the effects of climate change through reducing emissions and to adapt to the changing climate with sufficient and more efficient production.

The Intergovernmental Panel on Climate Change (IPCC) recently released the portion of its Fifth Assessment that addresses the physical science basis. Although the portion of the assessment addressing impacts, adaptation and vulnerability will not be released until March, 2014, the physical science assessment already provides new insights and improved projections that can begin to inform adaptation strategies, including in agriculture.

Maryland has been among the most progressive states in addressing the climate change challenge. A Climate Action Plan has been developed and legislation enacted setting the state policy of reducing its greenhouse gas emission by 25% by 2020. The Plan also includes commitments for adapting to anticipated climate changes and strategies are under development, guided by climate change impact assessments. These strategies include the relevant sectors of agriculture, forests and water resources. The University System of Maryland has also undertaken an Environmental Sustainability Initiative that extends from our academic and research programs and our own campus practices to the provision of expertise to inform policies, from local to global. Included within this portfolio is a comprehensive climate change education program (MADE CLEAR) that aims to make Marylanders the most climate literate in the nation.

At the Federal level, earlier this year President Obama released a Climate Action Plan to include activities within the executive branch. The Federal plan addresses the goal of protecting our economy and natural resources with the specific objectives of conserving land and water resources and maintaining agricultural sustainability. Bringing these Federal efforts together with the adaptation planning, research and education already under way in Maryland offers many timely opportunities for collaboration. At the same time, such efforts could clear new pathways for addressing the challenge of Chesapeake Bay restoration while also helping to limit climate change and increase our resilience to its effects.



Water Resources

Dr. Adel Shirmohammadi

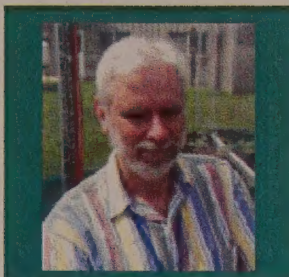
Professor, Associate Dean for Research and Associate
Director of Maryland Ag. Experiment Station
University of Maryland

Abstract

Water resources are a vital commodity globally, nationally, and regionally, especially in agriculture, which uses about 70 percent of fresh water. Recent variability in climatic patterns (e.g., uneven distribution of precipitation, rise in global temperature) has brought a significant stress on our water resources. The Ogallala aquifer is still declining despite employment of several efficient irrigation systems. National weather service data indicate an increase of about 1 degree centigrade in the Mid-Atlantic States, including Maryland, over the last 100 years. This increase corresponds to international data that shows a rise of about 1.2 degrees centigrade over the same period. In Maryland, the average monthly precipitation increased in March, April and May and decreased in June, July and August over the last century (1900-2000). This pattern of variability has resulted in farmers investing in overhead irrigation systems, thus creating an economic burden for producers as they adapt to climate change.

Such changes in climate will impact our national resources (Soil, Water and Air) in ways unimagined! For example, we may experience water table rise in coastal areas, thus taking land off of production and reducing the amount of potable water for human consumption. Such changes in hydrologic regime will result in reduced

accessibility to clean water for domestic use. It will also affect the quality of water by exacerbating flooding and chemical transport. How do we adapt to these conditions in light of climate change is one of the urgent and timely questions for our research and extension programs. We need to identify adaptation strategies (both research and education programs) to keep agriculture sustainable both economically and environmentally.



Biogeochemistry and Mitigation

Dr. Dennis Timlin

Research Soil Scientist

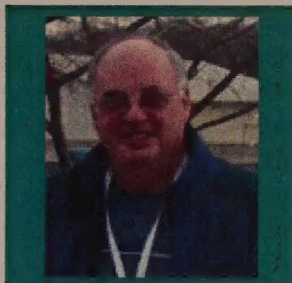
Crop Systems & Global Change Laboratory

Beltsville Agricultural Research Center

Abstract

Climate change not only affects agriculture, but agriculture, in turn, is a net contributor to greenhouse gas production. These gases consist primarily of carbon dioxide, but contain methane, nitrous oxides, and other complex carbon compounds. The potential impact of climate change on agriculture is large because production depends on almost entirely on weather, especially temperature and rainfall amounts and the stability of these factors. Because the production of these greenhouse gases is global in nature, control at the source is not always possible. Thus, we attempt to reduce the impact of global warming through strategies of adaptation and mitigation.

Such strategies involve breeding drought resistant and heat tolerant crops, sequestration of carbon in soil to remove it from the atmosphere, and reduction of the production of nitrous oxides and methane resulting from agricultural practices. There is also a social aspect to mitigation and adaptation in respect to how the general public is involved in these activities and how political and agricultural policies need to support one another. In this panel we will address these issues and discuss agricultural research carried on in the Chesapeake Bay region that contribute to solutions as the climate changes



Production Systems and Modeling

Dr. James Bunce

Professor, Associate Dean for Research and Associate
Director of Maryland Ag. Experiment Station
University of Maryland

Abstract

To understand the effects of rising levels of carbon dioxide, increasing mean temperatures, frequency of increasing hot spells and drought, and a combination of those factors, requires measuring the physiological responses and incorporating those measurements into crop prediction models under different climate scenarios. These predictions can be tested and used as decision support services to growers. The research will result in provide recommendations regarding selection of crop species and varieties within a species, planting dates, the need for irrigation, and pest control requirements. The crop simulation models can also be used at a larger scale to forecast regional crop production as a function of climate change and changes in management practices that would minimize loss and maximize crop production with climate uncertainty.

Poster Titles and Authors

1. ADAPTING AGRICULTURE TO CLIMATE CHANGE: CAN RISING CO₂ SPUR THE NEXT "GREEN REVOLUTION"?

L.H. Ziska¹, R.C. Sicher¹, J.A. Bunce¹
¹USDA-Agricultural Research Service,
Crop Systems and Global Change
Laboratory, Building 1, Room 323,
Beltsville Agricultural Research Center,
10300 Baltimore Avenue, Beltsville MD
20705

Agricultural production is under increasing pressure by global anthropogenic changes, including rising population, diversion of cereals to biofuels, increased protein demands, and climatic extremes. Because of the immediate and dynamic nature of these changes, adaptation measures are urgently needed to ensure both the stability and continued increase of the global food supply. Although potential adaption options often consider regional or sectoral variations of existing risk management (e.g., earlier planting dates, choice of crop), there may be a global-centric strategy for increasing productivity. In spite of the recognition that atmospheric carbon dioxide is an essential plant resource that has increased globally by ~25% since 1959, efforts to increase the biological conversion of atmospheric CO₂ to stimulate seed yield through crop selection is not generally recognized as an effective adaptation measure. Here we examine whether there is sufficient intraspecific variation among crop lines; specifically, wheat, rice, soybean and common bean, in order to begin breeding for CO₂ responsiveness. Overall, selection for increased conversion of rising CO₂ levels to seed yield may provide one of the simplest and direct strategies for increasing

global agricultural production and maintaining food security with anthropogenic change.

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2. A GENOME-WIDE ASSOCIATION STUDY OF BETWEEN COPY NUMBER VARIATION AND MILK PRODUCTION TRAITS IN HOLSTEIN POPULATION

Lingyang Xu^{1,2}, John B. Cole³, Yali Hou⁴,
Derek M. Bickhart³, Jiuzhou Song²,
Paul M. VanRaden³, Tad S. Sonstegard¹,
Curtis P. Van Tassell¹ and George E. Liu^{1,†}
¹Bovine Functional Genomics Laboratory,
BARC, USDA-ARS, Beltsville, Maryland
20705, USA; ²Department of Animal
and Avian Sciences, University of
Maryland, College Park, Maryland 20742,
USA; ³Animal Improvement Programs
Laboratory, BARC, USDA-ARS,
Beltsville, Maryland 20705, USA; ⁴Beijing
Institute of Genomics, Chinese Academy
of Sciences, Beijing, 100029, China

Milk production is an economically important sector of global agriculture, and much attention has been paid to identify quantitative trait loci (QTL) associated with these traits and investigate genetic and molecular mechanisms underlying them. Copy number variation (CNV) is an emerging variation which also could be associated with complex traits. In this study, we performed a genome-wide association between CNVs and milk production traits in approximately 26,400 Holstein bulls and cows. After a total of 99 candidate CNVs were identified using Golden Helix SVS based on Illumina

BovineSNP50 array data, association test for each production trait was performed using Correlation/Trend Test and single regression analysis with PCA correlation. A total of 35 CNVs from 22 chromosomes were detected as significantly associated with six milk production traits after false discovery rate (FDR) correction. Most of these CNVs were located in the known QTL regions for milk production traits. Further haplotype analysis for several key CNVs on BTA5 and BTA14 indicated that CNVs should be considered as new generation molecular markers to enhance animal production. We are comparing CNV-based GWAS with SNP-based GWAS in order to fully understand the genetic variations underlying milk production traits.

3. A GENOME-WIDE SURVEY REVEALS A DELETION POLYMORPHISM ASSOCIATED WITH RESISTANCE TO GASTROINTESTINAL NEMATODES IN ANGUS CATTLE

George E. Liu^{*1}, Lingyang Xu^{1,2}, Yali Hou³, Derek M. Bickhart⁴, Jiuzhou Song², Curtis P. Van Tassell¹, and Tad S. Sonstegard¹

¹Bovine Functional Genomics Laboratory, BARC, USDA-ARS, Beltsville, Maryland 20705, ²Department of Animal and Avian Sciences, University of Maryland, College Park, Maryland 20742, ³Beijing Institute of Genomics, Chinese Academy of Sciences, Beijing, 100029, China; ⁴Animal Improvement Programs Laboratory, BARC, USDA-ARS, Beltsville, Maryland 20705

Gastrointestinal (GI) nematode infections are a worldwide threat to human health and animal production. In this study, we

performed a genome-wide association study between copy number variations (CNV) and resistance to GI nematodes in an Angus cattle population. Using a linear regression analysis, we identified one deletion CNV which reaches genome-wide significance after Bonferroni correction. With multiple mapped human olfactory receptor genes but no annotated bovine genes in the region, this significantly associated CNV displays high population frequencies (58.26%) with a length of 104.8 kb on chr7. We further investigated the linkage disequilibrium (LD) relationships between this CNV and its nearby SNPs and genes. The underlining haplotype blocks contain immune related genes such as *ZNF496* and *NLRP3*. As this CNV co-segregates with linked SNPs and associated genes, we suspect it could contribute to the detected variations in gene expression and thus differences in host parasite resistance.

4. A MECHANISTIC APPROACH TO MODELING WATER UPTAKE AND CARBON ASSIMILATION IN MAIZE (*Zea Mays* L.) AT ELEVATED AND AMBIENT CO₂

Dennis Timlin^{*1}, Jong Ahn Chun², Soo-Hyung Kim³, David Fleisher¹, and V.R. Reddy¹ *Dennis.Timlin@ars.usda.gov, ¹USDA-ARS Crop Systems and Global Change Laboratory, Beltsville, MD 20705, ²APEC Climate Center, Busan, South Korea, ³University of Washington, Seattle, WA, 98195

Both transpiration and carbon assimilation are impacted by the carbon dioxide content of the atmosphere. This is because CO₂ diffuses onto water saturated surfaces within plant stomata. At high CO₂ concentrations, CO₂ diffuses rapidly into

stomata and therefore stomata do not have to remain open to the atmosphere for long periods of time. This results in lower transpiration rates per unit CO₂ assimilated. Maize (*Zea Mays* L.), however is a C4 plant, therefore carbon assimilation rate is not affected at CO₂ levels elevated above the current. Although carbon assimilation is not increased in Maize, transpiration does decrease at elevated CO₂. The objective of this study was to test a coupled model of photosynthesis and stomatal conductance implemented in a Maize simulation model (MAZSIM). MAZSIM uses a Farquhar type photosynthesis model coupled to a Ball-Berry stomatal control model. Non-linear beta functions are used to estimate the effects of temperature on photosynthesis, growth and development processes. The observed data come from experiments conducted in outdoor, sunlit growth chambers located at the USDA-ARS Beltsville Agricultural Research Center. The eight treatments comprised two levels of carbon dioxide concentrations (400 and 800 ppm) and four levels of water stress (well-watered control, mild, moderate, and severe). The water stress treatments were applied at both CO₂ levels. Water contents were monitored hourly by a Time Domain Reflectometry (TDR) system. The simulated carbon assimilation and water use values were close to the measured values and followed the experimental trends with CO₂ and irrigation. The model also simulated higher soil water contents in the high CO₂ treatment as compared to the low CO₂ treatment as was found in the measured data.

6. COMBINED EFFECTS OF CO₂ ENRICHMENT, DIURNAL LIGHT LEVELS AND WATER STRESS ON FOLIAR METABOLITES OF POTATO PLANTS GROWN IN NATURALLY SUNLIT GROWTH CHAMBERS.

Jinyoung Y. Barnaby, David Fleisher, Vangimalla Reddy and Richard Sicher, USDA-ARS, Crop Systems and Global Change Laboratory, Room 342, Building 001, BARC-west, 10300 Baltimore Avenue, Beltsville, Maryland, 20705

Drought treatments were imposed on potato plants (*Solanum tuberosum* L. cv. Kennebec) beginning ten days post-tuber initiation. Experiments were conducted in outdoor, naturally sunlit, soil-plant-atmosphere research (SPAR) chambers using plants grown in pots to assess water stress effects on leaf metabolites and interactions with CO₂ enrichment and changes in daylight. We observed that 23 of 40 metabolites were affected by drought when measured 11 d after initiating water stress treatments. Compounds that accumulated in response to drought were primarily hexoses, polyols, branched chain amino acids and aromatic amino acids. Conversely, alanine, aspartate and several important organic acids decreased due to insufficient soil moisture. More than 70% and 50% of the metabolites in this study that were affected by drought responded to day/night changes in light levels or to CO₂ treatments, respectively. In addition, over one-third of the water stress related metabolites in potato leaves interacted with both the CO₂ and daylight treatments.

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**7. COMPARATIVE GENOMICS
OF THE NEWLY EMERGENT
BOXWOOD BLIGHT PATHOGEN
Calonectria pseudonaviculata
REVEALS GLOBAL DIVERSITY IN
THE FREQUENCY OF THE MATING-
TYPE LOCUS**

Martha Malapi-Wight^{1,2}; Julie Hébert^{1,2};
Yazmín Rivera^{1,2}; Jo Anne Crouch¹

¹USDA-ARS, Systematic Mycology and
Microbiology Laboratory, Beltsville,
MD USA; ²Department of Plant Biology
& Pathology, Rutgers University, New
Brunswick, NJ 08901

Calonectria pseudonaviculata, a
destructive fungal pathogen responsible
for boxwood blight disease, has spread in
the past fifteen years throughout most of
Europe. Subsequently, the pathogen was
reported in North America in late 2011.
Affected plants show dark brown to black
spots or diffuse dark areas on leaves,
severe dieback and eventual plant death.
The factors driving the global dispersal
of this destructive pathogen are currently
undetermined. For plant pathogenic fungi,
generation of genetic diversity stemming
from sexual recombination is known to
facilitate the rapid adaptation of pathogens
to host resistance genes or fungicides or
lead to increased virulence. As such, an
understanding of the sexual reproductive
potential of *C. pseudonaviculata* holds
strong implications for boxwood blight
disease epidemiology, risk assessment
and the development of effective
control strategies. In this study, we used

comparative genomics to assess the
primary determinant of mating, the *MAT1*
gene, from a global population of 300 *C.*
pseudonaviculata isolates originating from
four continents. Genomic DNA libraries
for paired-end and mate pair reads were
constructed for fifteen *C. pseudonaviculata*
isolates using Illumina Nextera
tagmentation chemistry and sequenced
using an Illumina MiSeq instrument.
Four isolates representing the two major
subgroups of *C. pseudonaviculata* (G1
and G2) were sequenced to high depth
of coverage (310x to 58x; maximum
N50=60k); eleven isolates were sequenced
to an average coverage of 23x to 34x.
Genome assemblies were used to create
local BLAST databases and then searched
for homologues of the idiomorphic genes
MAT1-1 and *MAT1-2*. From each isolate,
only one of the two idiomorphs was
present in the genome at the *MAT1* locus,
indicating that *C. pseudonaviculata* is a
heterothallic fungus. Based on the genome
assemblies, two sets of PCR primers were
designed to amplify differently sized
regions of the *MAT1-1* and *MAT1-2* genes.
PCR products of the *MAT1-1* and *MAT1-2*
idiomorphs were sequenced, analyzed and
compared against the reference genome
assemblies of isolates CB45 (*MAT1-1*)
and cpsCT1 (*MAT1-2*) using BLASTn.
MAT1 nucleotide sequences of the 300
isolates showed 100% identity to the
reference isolate sequences. PCR analysis
showed that *MAT1-2* genotype is present
worldwide, but exclusively in the G1
lineage. *MAT1-1* is solely present in five
European countries from isolates of the G2
lineage. It is currently unknown whether
the G1 and G2 isolates are able to mate,
as extensive divergence between the two
lineages suggests that G1 and G2 may be
distinct species. 100% of the isolates from
North America were solely of the *MAT1-2*/

G1 genotype; therefore, our data suggest that the fungus is currently unable to reproduce sexually in the U.S.

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8. COTTON GROWTH RESPONSE TO PHOSPHORUS NUTRITION UNDER CURRENT AND PROJECTED CO₂ CONCENTRATIONS

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To study the cotton (*Gossypium hirsutum* L.) response to the combined effect of phosphorus and carbon dioxide (CO₂) concentration, plants were grown in six growth chambers with three levels of phosphate (Pi) supply (0.20, 0.05 and 0.01 mM) under current (400 µmol mol⁻¹) and projected (800 µmol mol⁻¹) CO₂ concentration for 95 days. Several growth and physiological measurements were made during and at the end of experiment. Irrespective of the growth CO₂, Pi deficient plants exhibited reduced leaf photosynthesis (Pnet) and were significantly shorter with decreased node numbers, leaf area, and total biomass (75-80%), as compared to the plants grown under optimum Pi supply. The decreases in rate of stem elongation and leaf area expansion were the main cause of smaller size of the plants in Pi deficiency. The stimulatory effect of elevated CO₂ on

Pnet was negligible under 0.01 mM Pi nutrition. In general, CO₂ enrichment failed to alleviate the negative effect of Pi deficiency on photosynthesis and reproductive structure (flower, square, and boll). However, small stimulatory effects of elevated CO₂ on plant height and total biomass were observed at all Pi nutrition. Irrespective of the Pi supply, photosynthetic acclimations of cotton plants to CO₂ enriched environments were evident from the reduced carboxylation efficiency of the photosynthetic processes. The results from this study indicated that the amount of available soil Pi will affect cotton growth and development independent of atmospheric CO₂ concentration. Particularly, processes such as photosynthesis and reproductive structures will be negatively affected by Pi deficiency even under high CO₂ environments of the future.

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9. DEVELOPING UNIQUE TRACERS TO DISTINGUISH NUTRIENT CONTRIBUTIONS FROM AGRICULTURE AND WASTEWATER SOURCES IN THE CHOPTANK AND ANACOSTIA RIVER WATERSHEDS

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Estuaries like the Chesapeake Bay are vulnerable to the effects of climate change. Some changes, such as the rise in sea level and temperature, can be predicted; however changes in precipitation patterns are more complicated to simulate.

Changes in precipitation patterns and sea level will likely affect nutrient inputs to the Bay and its tributaries as well as the relative contributions from agricultural runoff and wastewater treatment plants (WWTPs). However, when multiple sources are present within a watershed, it is often difficult to accurately estimate loads especially from non-point sources like agriculture. In this investigation, the impaired Choptank and Anacostia Rivers, tributaries of the Chesapeake Bay, are utilized as study areas. The aim of this work is to assess the use of chemical indicators as possible surrogate markers discriminating the nutrient contributions from agricultural versus urban sources. In the case of Choptank River, 13 sites were selected to include tidal and non-tidal waters. The Choptank River watershed contains heavy agricultural activity in the uplands and more residential areas near the mouth including two large WWTPs. For the Anacostia River 11 non-tidal and tidal sites were sampled. The Beltsville Agricultural Research Center is located in the upper Anacostia watershed and may be a significant source of agricultural nitrate and phosphorus. The remaining areas

of the watershed are either residential, urban, with some forested areas. Nutrient concentrations were determined at all sites using EPA approved methods, for total nitrogen, nitrate and nitrite, ortho-phosphorus and total phosphorus. In addition, chemical indicators were selected for testing. Compound selected were stable, soluble, and related solely to one type of source, either agricultural or WWTP. Metolachlor and its metabolites (herbicides) were selected as agricultural indicators of nutrient loading, while sucralose and acesulfame (artificial sweeteners) were selected as wastewater loading indicators. These analytes were simultaneously extracted from water samples by solid phase extraction (SPE) using OASIS HLB stationary phase and analyzed by liquid chromatography mass spectrometry (LC-MS). The methods developed in this project will be utilized to initiate a long-term project examining the strength of agricultural and urban sources of nutrients in each of these watersheds. This work will contribute to a greater understanding of the effectiveness of conservation efforts in reducing nutrient loading from two important sources to the Bay. This long-term dataset will also be useful for examining the effects of climate change on water quality within the larger Chesapeake Bay watershed and will aid states in meeting restoration efforts required by the US EPA.

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10. EVALUATION OF CLIMATE CHANGE ADAPTATION OPTIONS FOR AGRICULTURAL SYSTEMS

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Agricultural responses to climate change suggest an increased vulnerability of crop yields to elevated temperature, decreased water availability, and increased nutrient stresses. The EPIC (Environmental Policy Integrated Climate) model was used to evaluate the potential effects of climate change adaptations on crop yields, carbon respiration, soil carbon dynamics, and nitrate losses in runoff and leaching from representative farms in Alabama, Arkansas, Missouri, Mississippi, Florida, Kentucky, Louisiana, Texas, Georgia, and Tennessee. Adaptations included annual biochar applications, irrigation, and combined biochar and irrigation applications. Baseline (1979 – 2009) and future (2038 – 2068) scenarios were used for simulations with baseline and future CO₂ concentrations of 360 ppmv and 500 ppmv, respectively. Climatic data for baseline scenarios used NOAA's North American Regional Reanalysis (NARR) database. Climatic data for the future scenarios used the North American Regional Climate Change Assessment

Program (NARCCAP) database. Four regional climate models were used for the future simulations to project different patterns of changes in air temperatures, precipitation, and solar radiation that are expected to occur over time. Climate had significant effects on all response variables for at least 2 of the 4 regional climate models. Biochar treatments did not display significant increased yields that were different from the climate effects. Climate had a significant effect on nitrate leachate losses in comparison to the control for all the regional climate models. Although not significantly different from the other treatments, trends indicate that leachate nitrate losses were largest for the irrigation and climate treatments and lowest for the biochar treatment. The trends in the data suggest that biochar was not effective in reducing nitrate loss in runoff. Soil organic carbon dynamics displayed significantly higher accumulations of carbon for the biochar and combined irrigation and biochar treatments for all models. Under some weather scenarios, EPIC simulation results suggest that irrigation and biochar applications may be considered as promising potential adaptation strategies for agriculture in the Southeastern United States.

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11. HARLEQUIN BUGS ON LOCAL VEGETABLE CROPS: NEW TOOLS FOR PREDICTION AND MANAGEMENT

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New attractants are available for harlequin bug, a serious stink bug pest of vegetables in the mustard family such as cabbage, broccoli, collards, kale, mustard greens, and arugula. We are combining newly discovered and synthesized aggregation pheromones and plant-specific volatile mustard oils, to monitor, and also to trap or trap-crop harlequin bug to reduce its severity in urban gardens and small farms. Severe winter temperatures can result in high bug mortality, but this is not well-studied. Further research will investigate how warm microclimates associated with urban areas, cover crops and mulches, and warming climates, can favor harlequin bug overwintering survival, and how overwintered bug populations can be suppressed using cultural controls including our traps and/or trap plants.

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12. IMPATIENS UNDER ATTACK: GENETIC VARIABILITY OF THE OOMYCETE PATHOGEN *PLASMOPARA OBDUCENS* IN THE U.S.

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Impatiens downy mildew (IDM), caused by the fungus-like oomycete *Plasmopara obducens* (2n), is an aggressive, newly emergent disease affecting cultivated impatiens (*Impatiens walleriana*) in the U.S. The first U.S. IDM outbreak was reported in 2004. By 2012, IDM was reported from 33 states, resulting in millions of dollars in losses. The factors driving these destructive outbreaks are unknown. It is unclear whether IDM is caused by the same organism recorded on wild impatiens throughout the 20th century, or if disease outbreaks are due to a new pathotype or species. In this work, we set out to determine the pathogen population(s) responsible for IDM in cultivated impatiens, and compare these genotypes with pre-epidemic populations on wild impatiens. Single nucleotide polymorphism (SNP) analysis was performed using real-time PCR, droplet digital PCR and Sanger sequencing to genotype 87 pre-epidemic *P. obducens* herbarium specimens (c. 1881-2005) and 830 IDM samples from modern disease outbreaks. The sample was diverse, with six major genotypes (n>10) and 24 minor genotypes observed. Phylogenetic network

analysis showed reticulations reflective of hybridization or recombination between genotypic groups. Four major genotypes were exclusive to modern IDM samples (n=82). Two major genotypes were observed from both modern IDM samples and herbarium specimens (Genotype 1: 435 modern/1 herbarium; Genotype 2: 26 modern/60 herbarium). Droplet digital PCR revealed allelic ratios departing from 1:1 for multiple heterozygote samples, with a substantial number of samples exhibiting a 3:1 allelic skew. Because *P. obducens* cannot be cultured and DNA was extracted directly from environmental samples, the observed skew could be a result of mixed genotypes (populations) in individual samples, the presence of heterokaryotic isolates, or both. Together, our present dataset shows that although some *P. obducens* genotypes have been residing in the US since 1880's, other genotypes are unknown from pre-epidemic populations. Allele frequencies and network clusters suggest heterokaryosis and recombination as possible contributors to the observed population structure. Genome sequencing and flow cytometry are underway to quantify the impact of these processes on the emergence of *P. obducens* as a destructive pathogen of impatiens.

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13. MAPPING REGIONAL MODELING BACTERIA FATE AND TRANSPORT AT WATERSHED- SCALE USING FUTURE CLIMATE DATA

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It is widely accepted by the scientific community that global climate change (i.e. extremes of the hydrological cycle and global warming) will affect the dispersion of microbial organisms in the environment. However, uncertainty surrounding microbial fate and transport and host-environmental ecology renders predictions of the effects of climate change on human exposure to waterborne pathogens complex and difficult to forecast. If water quality is to be improved and maintained in the future, steps must be taken now to prepare for climate change, examine the exact nature and magnitude of these impacts, and adapt to possible scenarios that may arise. Hence, the objective of this study is to use watershed-scale water quality modeling applications to simulate climate change impacts on the fate and transport of waterborne organisms, assess future scenarios, and generate realistic adaption measures that can help to insulate water quality from forecasted weather extremes. Model development initially focuses on the calibration/validation of hydrology and

microbial loads using existing monitoring data (flow and bacteria), current climate data, and watershed/source characterization information. General Circulation Model (GCM) projections were subsequently downscaled to a format that can be coupled with existing watershed modeling applications and utilized at a localized watershed-scale. Potential scenarios are derived considering future climate impacts on land use and agricultural production systems, and consequences for microbial fate and transport. Simulation of microbial loads is based on downscaled GCM projections and future land use/source load scenarios at watershed scale. Outcomes of the study will reveal new information to assist in minimizing the effects of climate change on waterborne microorganisms. This will inform the amendment of required pollution control measures and aid development of new water policy.

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14. MONITORING WETLAND INUNDATION IN RESPONSE TO WEATHER VARIABILITY USING A MULTI-SENSOR APPROACH

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Wetlands provide a broad range of ecosystem services, including flood control, sediment and nutrient retention and export, water purification, groundwater replenishment, and rich biodiversity. The provision of these services is especially vital in the Chesapeake Bay Watershed. But many wetland areas in the Mid-Atlantic region are inundated or saturated for a relatively short period, usually in the spring after snowmelt and before leaf-out so monitoring the hydrologic condition of wetlands can be difficult. Remote sensing provides a major data source for monitoring wetland dynamics. The purpose of this study was to develop a new approach to map wetland inundation using combined data from airborne LiDAR (Light Detection and Ranging) and spaceborne Landsat. The results demonstrate that accurate maps of wetland inundation can be developed using this approach and that Landsat images can be calibrated to reveal the inundation state of wetlands over large regions. The importance of this finding is linked to the 40+ year continuous record of Landsat images, which can now be used to look at long-term trends in wetland hydrology. This will enhance our ability to detect influences of climate change on wetland ecosystems and the health of the Chesapeake Bay.

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15. PHYLOGEOGRAPHY OF THE BOXWOOD BLIGHT FUNGUS, *CALONECTRIA PSEUDONAVICULATA*

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Boxwood (*Buxus* sp.) are long-lived evergreen ornamental shrubs, popular in the landscape due to their shaping ability and deer-resistance. Boxwood is the most popular plant for topiaries; they are used in many U.S. historic sites, including the White House and Monticello, and are frequently planted on the grounds of golf courses and country clubs. A destructive new disease of boxwood, a blight caused by the ascomycete fungus, *Calonectria pseudonaviculata*, was first described in Europe in the 1990's and New Zealand in 1998. Boxwood blight was first reported in the U.S. states of Connecticut and North Carolina in October 2011. Within six months, the disease was reported in Maine, Maryland, New York, Ohio, Oregon, Pennsylvania, Rhode Island, and Virginia, as well as British Columbia and Ontario, Canada. More recently, the disease spread throughout the eastern seaboard into New Jersey, Maryland and Delaware. Boxwood blight causes rapid defoliation of infected plants, followed by death. Boxwood production is worth over \$100 million a year in the U.S., with 43% of revenue derived from states reporting boxwood blight.

It is important to understand how much genetic diversity is present in different populations of this fungus to predict how that diversity could impact the evolution of important phenotypes such as fungicide resistance. The objectives of this study were to develop genome-scale molecular markers in *C. pseudonaviculata* to estimate world-wide genetic diversity and to determine the source of the boxwood blight fungus in the United States. One hundred seventy-five isolates from Europe, Asia, the United States, and New Zealand were genotyped using AFLP markers. Data suggest at least two introductions of *C. pseudonaviculata* into the U.S., with subsequent movement of genotypes around the U.S. Estimates of genetic diversity were higher than expected for a recent introduction of what is considered a highly clonal species. In addition, multiple genotypes of fungus were collected from individual plants, indicating that plants may host populations of fungi rather than individual clones. If the increased genetic diversity is associated with increased phenotypic diversity, these data suggest that mitigation of *C. pseudonaviculata* will require study of multiple isolates of the fungus to best encompass the evolutionary potential of the pathogen.

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16. POULTRY INDUSTRIAL AMMONIA EMISSION MITIGATION BY EFFICIENT VEGETATIVE ENVIRONMENTAL BUFFERS

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Atmospheric ammonia is a key environmental concern with a positive feedback to the effects of climate change. Being an important precursor of particulate matter in the air, ammonia influences the atmospheric radiation balance. Ammonia has a very short half-life and is highly reactive with sulfuric and nitric acids. Ammonia is also an important component of aerosol formation which contributes a considerable amount (30% - 50%) to criteria air pollutants such as $PM_{2.5}$ and PM_{10} .

The expected increased global temperatures will contribute to more ammonia release from animal operations. The poultry industry has been considered one of the primary sources of ammonia emissions globally. Furthermore, the increased ammonia emissions due to global warming are likely to produce elevated particle matter in the atmosphere which will cause a cascade effect on the global climate system as a whole, affecting the C-N cycle, hydrological cycle, solar radiation, scattering, and other cloud characteristics.

This study aims to assess the use of vegetative environmental buffers to reduce ammonia and particulate emissions from the poultry houses. The poultry industry is a crucial part of the Delmarva Peninsula's economy with over 560 million broilers annually. Vegetative environmental buffers consist of certain kinds of trees, shrubs, and grasses. In this project, passive diffusive samplers (RadielloTM, Sigma Aldrich, Inc.) are employed to measure time-averaged atmospheric concentrations of ammonia and particles at multiple locations from the source. Our goal is to characterize the environmental fate of ammonia and particles as well as the efficiency of the vegetative buffers. These experiments will contribute to optimizing VEB designs for the ultimate purpose of minimizing emissions from the poultry industry.

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17. PRODUCTION CAPACITY AND CLIMATE CHANGE SENSITIVITY

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The eastern seaboard of the U.S. is a densely populated area that depends to a large extent on importing distantly

produced food to satisfy consumption demands. Food security and access can hypothetically be increased by promoting more reliance on regionally produced food. Quantifying the region's production capacity is thus an important component of studying regional food security issues. However, agricultural systems supplying regions like this one are vulnerable to uncertainties such as climate change that influence biophysical constraints to production capacity. Explanatory crop models have been developed to estimate yield, growth, and development of individual plants. These models are well-suited to the study of climate change effects on regional food security and potential adaptation strategies. USDA-ARS corn and potato models MAZSIM and SPUDIM were linked with a geospatial interface to study projected crop yields and resource utilization as influenced by physical soils properties, field management options, land-use characterization, and historical weather patterns at a sub-county spatial resolution. A spatially-referenced yield index (YI) was developed to aggregate the results from both models, create an estimate of baseline productivity over the region, and provide a simple numerical analogue for production potential. The sensitivity of this index was evaluated with respect to changes in climate (temperature, precipitation, and atmospheric carbon dioxide) and management options for rain-fed (WL) or fully irrigation (NL) production. Future climate, and impact on yields and YI, was simulated by adjusting monthly statistics used by the weather generator CLIGEN based on downscaled data for A2 and B2 emissions scenarios from the Intergovernmental Panel on Climate Change. The results of this study could be used by regional planners to

anticipate future climate change risks and evaluate adaptation strategies including crop management practices and studying alternative land-use configurations.

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18. REFINING EXPECTATIONS OF SOIL ORGANIC CARBON STORAGE UNDER FUTURE CLIMATE CHANGE USING OBSERVATIONAL STUDIES

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The effects of multiple global change factors on soil carbon stocks are difficult to capture in short-term experiments. Urbanization and other microsite qualities can impose long-term, gradual increases in temperature, carbon dioxide and ozone levels that fluctuate over time and interact freely with other ecosystem attributes. These increases can simulate realistic, near-future climate change conditions. At 62 golf courses in the temperate, mesic, mid-Atlantic region of the U.S., I conducted an observational study of soil carbon in minimally managed soils at varying distances from urbanized areas, where cool-season turfgrasses had been grown without soil disturbance for ≥ 25 years. Replicate soil cores were taken to

a depth of 30 cm, hourly soil temperatures were recorded for seven months, tropospheric ozone levels were passively monitored during the late-summer peak season, and site and management variables were recorded. Soil chemistry, texture, and total and active carbon content were measured from the composite soil core samples. Correlations of total and active soil carbon with potential explanatory factors were explored using multiple regression analysis.

Total soil carbon was positively correlated with increasing February-only mean daily minimum soil temperature, which ranged from 0.3 - 2.7 °C. Mechanisms may include freeze/thaw disruption and subsequent mineralization of soil organic carbon, and/or reduced plant inputs to soil resulting from increased cold stress. No relationships were detected between total or active soil C and overall mean Dec.-May temperature, which ranged from 6.0 - 9.0 °C, or maximum May-only temperature, which ranged from 18.0 - 23.3 °C. Total and active soil carbon were positively correlated with increasing ozone levels and negatively correlated with fertilization; potential mechanisms include recalcitrance of ozone-oxidized plant tissues, ozone inhibition of soil microbial respiration, and fertilizer-induced carbon consumption by soil microbial biomass. Total soil carbon was also positively correlated with soil lead content and CEC. Together, the suite of detected correlations suggests that within a climatic region, factors impacting soil carbon availability explain a large part of the variation in soil carbon storage. These results also highlight that small increases in temperature ranges can have important effects, and that commonly-held expectations based on controlled

experiments and models are not always observed in complex natural systems.

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19. USE OF GENOME-WIDE ASSOCIATION MAPPING TO IDENTIFY CHROMOSOMAL REGIONS ASSOCIATED WITH RECTAL TEMPERATURE DURING HEAT STRESS IN HOLSTEIN CATTLE

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Dairy cattle experiencing heat stress have reduced production, fertility, and health compared to non-heat stressed animals, and dairy cattle in the southern US commonly are heat-stressed for at least some of the year. Most of the negative effects of heat stress on animal performance are a consequence of either physiological adaptations to regulate body temperature or adverse consequences of failure to regulate body temperature. One strategy for mitigating those negative

effects is to select individuals that are genetically resistant to heat stress, and the ability to maintain a constant body temperature during heat stress could increase thermotolerance. The objective of this study was to perform a genome-wide association study (GWAS) for rectal temperature (RT) during heat stress in lactating Holstein cows and identify SNPs associated with genes that have large effects on RT. Records on afternoon RT where the temperature-humidity index was ≥ 78.2 were collected from nine commercial dairies in northern Florida. Phenotypes were collected for 4,447 lactating Holstein cows sired by 220 bulls, resulting in 1,440 useable genotypes from the Illumina BovineSNP50 BeadChip (Illumina, Inc., San Diego, CA) with 39,759 SNP. (Co)variance components and breeding values were calculated using the AIREMLF90 and BLUPF90 software packages from the University of Georgia (Athens). The GWAS was performed with a single-step procedure as implemented in the POSTGSF90 software. For the GWAS, 2, 3, 4, 5, and 10 adjacent SNP were averaged to identify consensus genomic regions associated with RT. The largest proportion of SNP variance (0.07 to 0.44%) was explained by markers flanking the region between 28,877,547 and 28,907,154 bp on *Bos taurus* autosome (BTA) 24. That region is flanked by U1 (28,822,883 to 28,823,043) and NCAD (28,992,666 to 29,241,119). In addition, the SNP at 58,500,249 bp on BTA 16 explained 0.08% and 0.11% of the SNP variance for 2- and 3-SNP analyses, respectively. That contig includes SNORA19, RFWD2 and SCARNA3. Other SNP associated with RT were located on BTA 16 (close to CEP170 and PLD5), BTA 5 (near SLCO1C1 and PDE3A), BTA 4 (near KBTBD2 and

LSM5), and BTA 26 (located in GOT1, a gene implicated in protection from cellular stress). There do appear to be QTL associated with RT in heat-stressed dairy cattle, but the QTL explain relatively small proportions of overall additive genetic variance. These SNP could prove useful in genetic selection and for identification of genes involved in physiological responses to heat stress.

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20. UTILIZING ELECTRONIC NOSE AND GC-MS TO EXAMINE CRITICAL FACTORS INFLUENCING THE FORMATION OF ODOROUS VOC IN BIOSOLIDS TO SUPPORT AN ODOR MONITORING PROGRAM.

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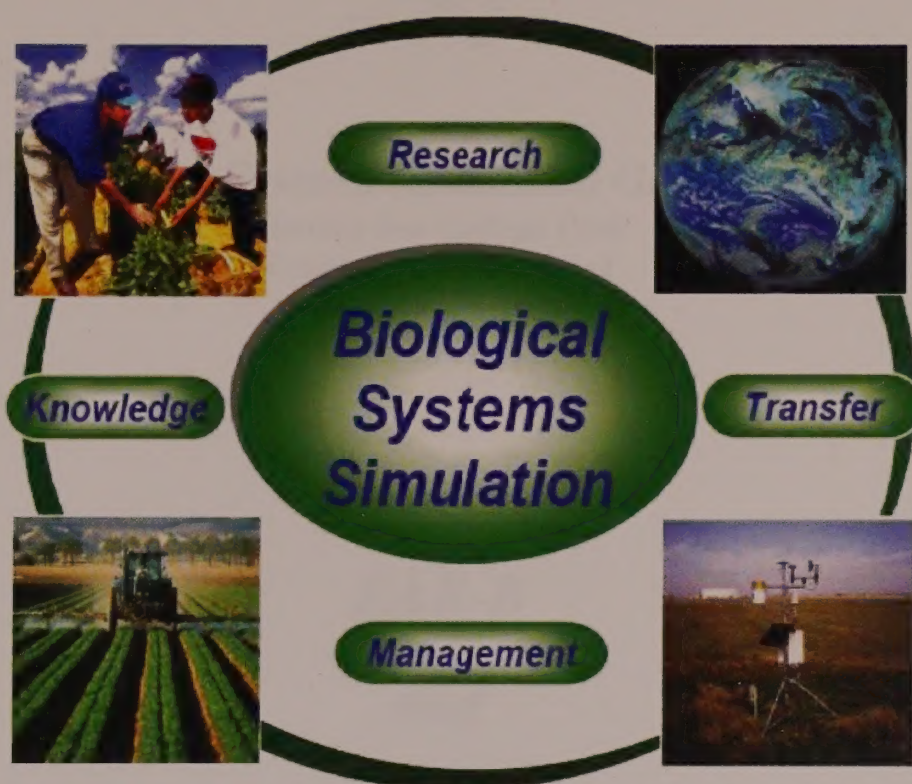
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Symposia

1. Virology in Agriculture
May 10-12, 1976
2. Biosystematics in Agriculture
May 8-11, 1977
3. Animal Reproduction
May 14-17, 1978
4. Human Nutrition Research
May 8-9, 1979
5. Biological Control in Crop Production
May 18-21, 1980
6. Strategies of Plant Reproduction
May 17-20, 1981
7. Genetic Engineering: Applications to Agriculture
May 16-19, 1982
8. Agricultural Chemicals in the Future
May 16-19, 1983
9. Frontiers of Membrane Research
May 20-24, 1984
10. Biotechnology for Solving Agricultural Problems
May 5-9, 1985
11. Instrumentation in Agricultural Research
May 4-8, 1986
12. Biomechanisms Regulating Growth and Development: Keys to Progress
May 3-7, 1987
13. Biotic Diversity and Germplasm Preservation
May 9-11, 1988
14. The Rhizosphere and Plant Growth
May 8-11, 1989
24. Healthy Animals 2000
September 2000

37th Annual
**Biological Systems
Simulation Conference**
April 17-19, 2007

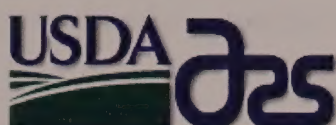
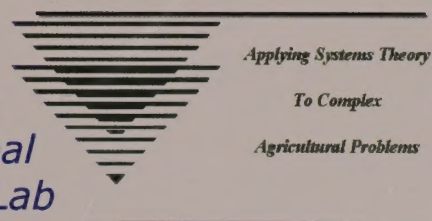


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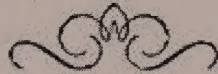


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Program and Abstracts



37th Biological Systems Simulation Group Workshop

Holiday Inn College Park

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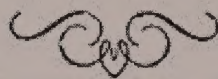
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Acknowledgement:

Special thanks to the Crops Systems and Global Change Laboratory staff for their efforts toward making local arrangements and preparation of the proceedings

Conference Organizers

V.R. Reddy, USDA-ARS

David H. Fleisher, USDA-ARS

Dennis Timlin, USDA-ARS

Soo-Hyung Kim, University of Washington

Bruno Quebedeaux, University of Maryland

Laj Ahuja, USDA-ARS

Jeff Baker, USDA-ARS

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April 17

Time	Title	Author(s)
7:30-8:30	On-Site Registration / Poster set-up	
7:30-8:30	Continental Breakfast	
8:30-8:40	Opening Remarks / Logistics	David H. Fleisher
8:40-8:50	Welcome	Phyllis Johnson, Director, Beltsville Area USDA- ARS
Session 1.1 Nutrient / Water Uptake and Root Growth		
Moderator: David H. Fleisher		
8:50-9:10	Invited Talk: State of the Art Modeling of Nutrient Uptake / Root Growth	Ken Boote
9:10-9:40	Invited Talk: Challenges or Taunts, from the Soil-Crop N Cycle for Agriculture Scientists	Jack Meisinger
9:40-10:00	Root Growth and Water and N Uptake in Corn under Different Levels of Water Application	Laj R. Ahuja*, S.A. Saseendran, L. Ma, and A.A. Andales
10:00-10:20	Modeling Fine Root Function and Development	Rich W. Zobel
10:20-10:45	Catered Break	
10:45-11:05	Fundamentals of Routines of Uptake of Water and Nutrients and Growth of Root Systems	Peter de Willigen*, M. Heinen, and A. Mollier
11:05-11:25	Simulating Root Density Dynamics and Nitrogen Uptake - Is a Simple Approach Sufficient?	Anders Pedersen*, K. Zhang, and K. Thorup
11:25-11:45	An Approach for Predicting One and Two Dimensional Root Growth in the CROPGRO Model as a Function of Soil Properties	Ken J. Boote*, G. Hoogenboom, J. W. Jones, F. Sau, F. Villegas, and C. H. Porter
11:45-12:05	Discussion / Summary of Session 1.1	
12:05-1:20	Catered Lunch	

Session 1.2 General Modeling Paradigms / Approaches To Improve Models
Moderator: Laj Ahuja

1:20-1:40	The NICOLET Model: Carbon, Nitrogen and Water in Leaves	Ido Seginer
1:40-2:00	Development of a Generic Crop Modeling Framework	Myriam Adam*, F. Ewert, P. Leffelaar, B. Rapidel, J. Wery, and H. van Keulen
2:00-2:20	Simulating Canopy Evapotranspiration and Photosynthesis of Corn Plants Under Different Water Status Using a Coupled MaizeSim+2DSOIL Model	Yang Yang*, D. Timlin, D.H. Fleisher, and V.R. Reddy
2:20-2:40	Source-limited and Sink-limited Kernel Set: Two Complementary Approaches to Simulate Kernel Number with CERES-Maize	Jon I. Lizaso*, A.E. Fonseca, and M.E. Westgate
2:45-3:10	Catered Break	
3:10-3:30	Initializing Soil Carbon Models for Agricultural Systems	Osvaldo Gargiulo*, J.W. Jones, A.J. Gijssman, and K. Jawoo
3:30-3:50	Simulated Nitrogen Management Effects on Soil Organic Carbon Fractions	Osvaldo Gargiulo*, J.W. Jones, A.J. Gijssman, and J. Koo
3:50-4:10	Simulating Fresh Mass Yield and Potato Tuber Size Distribution with CSM-SUBSTOR	Jon I. Lizaso*, K.J. Boote, J.M. Scholberg, and J.W. Jones
4:10-4:30	Regression-Based Analysis of Modeled Responses to Water Deficits in Wheat and Common Bean	Jeff W. White*, G. Hoogenboom, M. Herndl, and G.S. McMaster
4:30-4:50	Discussion / Summary of Sessions 1.1 and 1.2	

April 18

Time	Title	Author(s)
7:30-8:30	On-Site Registration / Poster set-up	
7:30-8:30	Continental Breakfast	
Session 1.3 CO₂, Drought, Nutrient Responses and Modeling Considerations Moderator: Soo-Hyung Kim		
8:30-9:00	Invited Talk: Agricultural Productivity and Climate Change: Challenges and Opportunities	Lewis Ziska
9:00-9:20	Cotton Growth, Development and Physiology as Affected by Nitrogen Nutrition and Elevated Carbon Dioxide: Developing Functional Algorithms for Modeling	K. Raja Reddy
9:20-9:40	Regulation of Active and Passive Nitrogen Uptake in Response to CO ₂ and Nitrogen Application Rate	Dennis J. Timlin*, D. Fleisher, Y. Yang, M. Kouznetsov, V.R. Reddy, and Y. Pachepsky
9:40-10:00	Responses of Grain Sorghum to Short Episodes of Water Deficit and/or High Temperature Stress: Challenges and Opportunities to Crop Models	Vara Prasad*, R.R. Mutava, S.R. Pisipati, and M.R. Tuinstra
10:00-10:25	Catered Break	
10:25-10:55	Invited Talk: Impact of Elevated Carbon Dioxide Concentration on Nitrogen Uptake in Rice	H. Shimono and James Bunce*
10:55-11:15	Modeling to Evaluate Irrigation Management Strategies to Maximize Cotton Yield and Water Use Efficiency	R.Louis Baumhardt*, S. Staggenborg, P. Gowda, and P. Colaizzi
11:15-11:35	Development of an Integrated Agricultural Information and Management System	Lloyd Ted Wilson*, Y. Yang, J. Wang, and P. Lu
11:35-11:55	Development of an On-Farm Rice Water Conservation Analyzer	Yubin Yang*, L.T. Wilson, J. Wang, and P. Lu
11:55-12:15	Discussion / Summary of Session 1.3	

12:15-1:30 Catered Lunch

Mini-Session 1.4 Modeling Opportunities

Moderator: Jeffery White

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|------------------|---|--|
| 1:30-2:00 | Invited Talk: Uses and Challenges for Modeling Sustainable Agricultural Systems | John Teasdale |
| 2:00-2:20 | Plant Microbe Interactions in Wheat Affected by Different Temperatures | Zumrad A. Tulyasheva* and D. Egamberdiyeva |
| 2:20-2:30 | Discussion / Summary of Mini-Session 1.4 | |
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2:30-5:00 Session P1: Poster and Software Demonstrations

Moderator: Jon Lizaso

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| Use of Functional Mapping to Identify QTLs of Root Traits of the Common Bean | Y. Fu, C. E. Vallejos, and Melanie J. Correll* |
| A Dynamic Model of Water Potential and Movement in Whole Plants Based on Compartment Volumes and Water Contents | Martin P.N. Gent |
| Global Solar and Meteorological Data for Agricultural Applications | Jim M. Hoell*, P. Stackhouse, W.S. Chandler, D. Westberg, C.H. Whitlock, and T. Zhang |
| Impact of Water Availability on the Co-existence of Grasses and Legumes in Simulated Mixed Swards | Patrick Lazzarotto*, P. Calanca, and J. Fuhrer |
| An Explicit Model of Canopy Structure to Compare Absorbed Light Distributions in Maize | N. B. Loosmore, Soo-Hyung Kim* and E. D. Ford. |
| A Crop Simulation Model for Potato Cropping Systems | J. Marcos, C. Stockle, Ashok Alva*, V.R. Reddy, and D. Timlin |
| Effects of Nitrogen Deficiency on Plant Growth and Photosynthesis, and Selection of Reflectance Properties for Physiology in Switchgrass | S.S.K.Matcha, V.G. Kakani, and K.Raja. Reddy* |
| Coupling of a Crop Model with FUSSIM2 to Simulate Maize Crop Responses to P-uptake | A. Mollier, Peter de Willigen*, M. Heinen |

Modification and Calibration of a Simple Semi-mechanistic Model of Phosphorous Uptake of Wheat Growing in an Andisol Soil

Dante Pinochet*, A. Fernandez, D. Calderini, and R. Fuentes

Nitrogen and Irrigation Management of Sweet Sorghum in Texas

Wes Rosenthal*, W. Harman, J. Blumenthal, and W. Rooney

Towards an Equilibrium P-fertilization of Vegetable Crops: Modeling the Effect of P Placement

A.L. (Bert) Smit*, A.A. Pronk and P. de Willigen

On The Use of Radiation and Water-use Efficiency for Biomass Production Models

Claudio O. Stockle*, A. R. Kemanian, and C. Kremer

Software Demo: C-FARM: A Simple Model to Evaluate the Carbon Balance of Soil Profiles

Armen R. Kemanian*, C. O. Stöckle², D. R. Huggins, V. S. Manoranjan⁴, and J. Marcos

Software Demo: Raithu 2006 - Cotton Model with Advanced Analysis Approaches

Timmavajjula G. Krishna*, P.C.C. Mouli, K. Raghavendra, T.Y. Reddy, and V.R. Reddy

5:30-6:30 HAPPY HOUR (Cash Bar)

6:30-9:00 BUFFET DINNER

Invited Speaker: Ghassem R. Asrar, Deputy Administrator, Natural Resources and Sustainable Agricultural Systems, USDA-ARS

Entertainment: Painted Trillium (Celtic music)

April 19

Time	Title	Authors
7:30-8:30	Continental Breakfast	
Session 1.5 Other Model Applications and Decision Support		
Moderator: Ken Boote		
8:30-9:00	Invited Talk: Remote Sensing to Test Distribution Models of Invasive Species	E. Raymond Hunt, Jr.
9:00-9:20	Integration of MODIS Products and a Crop Simulation Model for Crop Yield Estimation	Hongliang Fang*, S. Liang, and G. Hoogenboom
9:20-9:40	Modeling the Effects of Processed-kaolin Particle Films on Gas-exchange of Fruit Tree Leaves	Soo-Hyung Kim* and D.M. Glenn
9:40-10:00	The Adaptability of the Soybean Model, GLYCIM, for Tropical Conditions	Suresh B. Lokhande*, V.M. Salokhe, V.R. Reddy, and D. Timlin
10:00-10:20	Biological-Mathematical Models and New Theorems	Ricardo Sanchez
10:20-10:45	Catered Break	
10:45-11:30	Discussion / Summary of Session 1.5 and General Conference Comments	
	Selection of Venue for 2008 BSSG Conference	
	END – OF – CONFERENCE	
	LUNCH ON OWN	
1:30-4:30	Post-Conference Tour of BARC (meets in hotel lobby)	

* Denotes presenting speaker.

State of the Art Modeling of Nutrient Uptake / Root Growth

K. J. Boote

University of Florida, FL, USA. kjb@ifas.ufl.edu

This presentation is an overview of the state of the art of modeling approaches for nutrient uptake and root growth. Nutrient uptake and water uptake share many important linkages with root growth; thus the modeled root growth pattern, both seasonally and vertically with depth, determines the potential ability to take up water and nutrients which vary also with vertical profile depth. This presentation will discuss root growth concepts linked to (1) plant carbon balance and crop life cycle, (2) the effects of plant-internal limiting factors on root growth (e.g., water deficit, N deficiency, or P deficiency which cause shift in partitioning of assimilate to root growth), (3) static and dynamic soil factors that affect root growth (e.g., soil Al, soil Ca, soil temperature, soil strength and aeration from the interaction of soil water status and soil texture), and (4) signaling (growth regulators) from roots to shoots. Several approaches for simulating root growth will be discussed such as: (1) simulating simple one-dimensional (1-D) patterns, (2) simulating complex geometry with angularity, and (3) simulating 2-D or 3-D rooting patterns. The method used in the DSSAT models (a simple form of 1-D root distribution pattern) will be presented along with simulated output of root length density over time and depth. The Jones et al. (1991) root growth model is a dynamic form of the 1-D approach that is based on soil static and dynamic properties. While this module has not been incorporated into whole crop growth models, its valuable features deserve to be used, but with improvements to include effects of soil P and N fertility status on root proliferation

Nutrient uptake concepts will include discussion of the theory and approaches of Barber (1995) (involving interception, mass flow, and diffusion of nutrients such as N, P, K to roots, considering solubility, diffusivity, and soil buffering power). These mechanistic methods deserve strong consideration for incorporation into current crop models, but there are few of these soil fertility scientists left. Despite the use of Michaelis-Menten kinetics, the Barber models show strong dependency of nutrient uptake on root length density and the need for nutrient demand (upper limit) to be set by plant carbon supply. Various ways of computing crop nutrient demand from today's growth increment and a "deficit" uptake demand will be discussed. Nutrient demand versus nutrient uptake will be discussed in light of whether the plant carbon balance or potential nitrogen uptake is driving the system. There is also a question of how nutrient deficit effects act on plant growth to cause decreased assimilation, shift in partitioning, modified development rate, and reduced leaf area expansion, etc.

References

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- Jones, C. A., W. L. Bland, J. T. Ritchie, and J. R. Williams. 1991. Simulation of root growth. p. 91-123. In J. Hanks and J. T. Ritchie (eds.) Modeling Plant and Soil Systems. ASA-CSSA-SSSA, Madison, WI.

The presentation is an overview of the state of the art of studying psychiatric disorders in children and adolescents. It is a review of the current state of knowledge in the field of child and adolescent psychiatry, with particular emphasis on the study of the human brain. The presentation is organized into three main sections: (1) the study of the human brain, (2) the study of the human mind, and (3) the study of the human behavior. The first section, the study of the human brain, is divided into two sub-sections: (a) the study of the human brain in health, and (b) the study of the human brain in disease. The second section, the study of the human mind, is divided into two sub-sections: (a) the study of the human mind in health, and (b) the study of the human mind in disease. The third section, the study of the human behavior, is divided into two sub-sections: (a) the study of the human behavior in health, and (b) the study of the human behavior in disease. The presentation is a comprehensive overview of the current state of knowledge in the field of child and adolescent psychiatry, with particular emphasis on the study of the human brain.

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Challenges or Taunts, from the Soil-Crop N Cycle for Agricultural Scientists

J.J. Meisinger

USDA-ARS

The soil-crop N cycle has provided challenges, enigmas, and outright taunts to agricultural scientists for nearly 175 years. One of the most recent puzzles has arisen from the common observation in multi-year, or multi-location, N-response studies that the soil-plant system is able to vary plant available N with growing conditions. This characteristic is not a newly discovered attribute, but is being re-examined under the term "Soil-Plant N Resiliency". The importance of soil-plant N resiliency has not been fully appreciated, probably because it involves the interdisciplinary functioning of the N cycle.

Nitrogen resiliency is a general biological characteristic of the soil-plant N cycle that is thought to be caused by both soil and crop factors that interact with each other, and the environment, to produce higher grain yields on N-stressed plots in years with high-yield potentials and lower yields on the same plots in low-yield potential years. Some possible soil factors contributing to N resiliency are higher organic-N mineralization rates in good years, and/or higher N recovery efficiencies resulting from lower leaching and/or lower denitrification losses. Potential crop factors contributing to resiliency include a higher percentage distribution of fixed C into the grain compared to the roots in good years, or simply a greater total production of dry matter. The weather in high-yield years also interacts with N resiliency components with high solar radiation and ample rainfall contributing to higher photosynthesis vs. respiration rates, and/or higher transpiration rates that would transport more nitrates to the crop root surfaces. The above explanations are necessarily speculative, because soil-plant N resiliency has not been systematically studied. Hopefully, the challenges raised by N resiliency will encourage future research studies that will expand our understanding of this characteristic. An increased comprehension of N resiliency would improve its application to N recommendations, could identify management practices to enhance resiliency, and would encourage more interdisciplinary research between soil scientists, crop scientists, and modelers.

Root Growth and Water and N Uptake in Corn under Different Levels of Water Application

L.R. Ahuja, S.A. Saseendran, L. Ma, A.A. Andales

USDA-ARS, Agricultural Systems Research Unit, Fort Collins, CO

We recently used a field-validated DSSAT Version 4.0 model to study the response of corn to different levels of water application from 10 to 100 cm during the growth period over 90 years of weather data from Akron, CO, with and without the natural rain. Each given total irrigation amount was applied under three different scenarios: 1) the water was divided equally between vegetative and reproductive growth stages; 2) a 20-80% split between these stages; and 3) and 40-60% split. The yield response of the crop, as well as water and N uptake were of major interest, but we simulated other parts of the system as well. In this study, we will analyze the overall root growth and root density distribution in the soil profile, in relation to water and N uptake at different levels of water application. This analysis will give us a better understanding of the root growth-uptake interactions. It will also shed light on the needed improvements in simulating root growth and uptake processes.

Modeling Fine Root Function and Development

R.W. Zobel

USDA-ARS, Appalachian Farming Systems Research Center, Beaver, WV, 25813

Keywords: Roots, Root Types, Heritability, Root Function

The efficacy of root system structural and functional models is necessarily dependent on their ability to mimic real root system structure and function. Unfortunately the available data from which model parameters can be drawn is extremely sparse, both in a species/cultivar and dicotyledon vs. monocotyledon context. What data there is, is often confusing as to the actual type of root being discussed.

Structure of the primary root system has been shown to be controlled by at least four different genetic systems, with concomitant structural and functionally differential responses (Zobel, 1975; Zobel et al. 1992; Bushamuka and Zobel, 1998). However, the nomenclature has only recently clarified the primary root system root types (Zobel, 1991; Gregory, 2006). The International Society for Root Research recommended that the nomenclature be modified from Zobel (1991) to replace the term “adventitious roots” for the more descriptive term “Shoot Borne Roots” (cited in Gregory, 2006; and Zobel, 2005a). The term “adventitious” has a restrictive anatomical definition which is correctly applied to an entirely different type of root that branches off of older roots, as demonstrated by Paollilo and Zobel (2002). The differences in development between lateral roots and Paollilo and Zobel’s adventitious roots suggest the possible existence of a fifth type of root, but this must wait for further research.

Fine roots with diameters to 0.06 mm have been described for many plant species (Lyford, 1975, Wright, et al., 1999, Zobel, 2005b), and are termed the tertiary root system (Zobel, 2005b). These roots, often comprising up to 90% of total root length, are the primary source of nutrient and water uptake in non-seedling plants. Mounting evidence suggests that fine roots are not all genetically, developmentally or physiologically identical (see the overview by Zobel, 2005b). Recent evidence suggests the action of at least two distinct, phosphorus-responsive, genetic/morphological systems in these fine roots (based on diameter classifications and response to P deficiency - Zobel et al., 2006; Zobel et al., 2007). The research of McCully (1987) with maize, and discussed for maize by Cahn et al. (1989) and other species by Zobel (2005b), demonstrate that the finest roots are often determinate in growth and short lived.

Zobel (2005b) points out that short, thin roots that are also short-lived provide the root system with an evolutionary/ecologically sensible method of dealing with transient patches of nutrients and water. In addition, it is suggested that these thin, short-lived roots are priming the rhizosphere to release additional bound nutrients for the benefit of succeeding cohorts of thin short roots (Zobel, 2005b). Using data from Huck et al. (1987) with rhizotron observations every 48 hours, combined with personal field observations, Zobel (2005b) suggests that these short thin roots live only 14 days. The existence of the observed short root turn over combined with the growth patterns of the adventitious roots of Paollilo and Zobel (2004) suggests a mechanism of root growth, death, and renewal for dicots, but not monocots.

Taking the above discussion at its most liberal interpretation, there are at least 7 different (five primary and two tertiary) genetic, developmental, physiological systems associated with root growth and function. This hypothesis would explain the rather low heritability often observed with genetic analyses of root function. Based on this hypothesis, if a researcher indiscriminately harvests (samples) roots without regard to “type”, they will recover a mixed bag of physiological/genetic material. The Bushamuka and Zobel (1998) data support the concept that the separation of roots into distinct classes prior to analysis will yield more uniform response patterns within a type and, therefore, increased apparent heritability. This interpretation suggests high heritability within root type, and therefore offers discrete (if relatively numerous) modeling approaches rather than random number generators or black boxes.

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Fundamentals of Routines of uptake of Water and Nutrients and Growth of Root Systems

P. de Willigen¹, M. Heinen² and A. Mollier³

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The routines describing the uptake of water and nutrients by the roots are based on analytical solutions of single root models. Water uptake is described as a chain process with steady-rate transport in soil and steady-state transport in the root (de Willigen *et al.*, 2005). Nutrient uptake is based on steady-rate transport in soil and/or zero-sink uptake by the root (de Willigen and van Noordwijk, 1994 a and b, de Willigen *et al.*, 2000).

Both uptake mechanisms are up-scaled from a single root to a root system. We will discuss the justification of our approximations and demonstrate the flexibility of our models. In case of water uptake for instance the model is able to reproduce the phenomenon of hydraulic lift, whereas the nutrient uptake models shows enhanced uptake of those parts of the root system in favorable situation as far as nutrient supply is concerned to compensate for the low uptake rate of roots in poor conditions. We will show examples of validation studies.

Extension of the root system is described as a diffusive process in two dimensions (deWilligen *et al.*, 2002). We will show the validity of this description and illustrate this with examples. The routines form a part of the simulation model FUSSIM2, a two-dimensional simulation model, fit both for rectangular and cylindrical geometry, for describing water movement, solute transport and root uptake of water and nutrients in partially saturated porous media (Heinen, 2001). Some attention will be paid to the coupling of FUSSIM2 to a model dealing with above-ground crop growth (*see also the poster of A. Mollier et al. in this conference*).

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Simulating Root Density Dynamics and Nitrogen Uptake – Is a Simple Approach Sufficient?

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Keywords: modeling, root profilation, root density, nitrogen uptake

The modeling of root growth in many plant–soil models is simple and with few possibilities to adapt simulated root proliferation and depth distribution to that actually found with different crop species. Here we propose a root model, developed to describe root growth, root density and nitrogen uptake. The model focuses on annual crops, and attempts to model root growth of different crop species and row crops and its significance for nitrogen uptake from different parts of the soil volume.

The presented model was built on a simple approach, however with the capacity to simulate different root distribution patterns by changing only one parameter, namely a root form factor which controls the root density in different soil layers. Root density is calculated by a modification of the Gerwitz and Page (1974) equation for root length density, in their approach root density at the bottom of the root zone was set to a fixed value whereas the root form parameter changes during the growth season. We set a fixed value for the root form parameter for root density distribution and let the root density at rooting depth be variable.

In Figure 1 the root model flexibility is illustrated. The figure shows a situation where all parameters are equal except the form factor value (a_z). By changing the form factor from 0 to 3 or 8 it is possible to simulate a wide range of root density profiles (Figure 1, Left part). This results in significantly different patterns in soil nitrogen uptake from different layers in the soil profile (Figure 1, Right part). By combining root form parameter, root penetration rate, root/shoot ratio and root N uptake rate, it will be possible to adapt this simple root model to simulate nitrogen uptake dynamics in a realistic way in soil-plant simulations models (Pedersen et al. in prep.).

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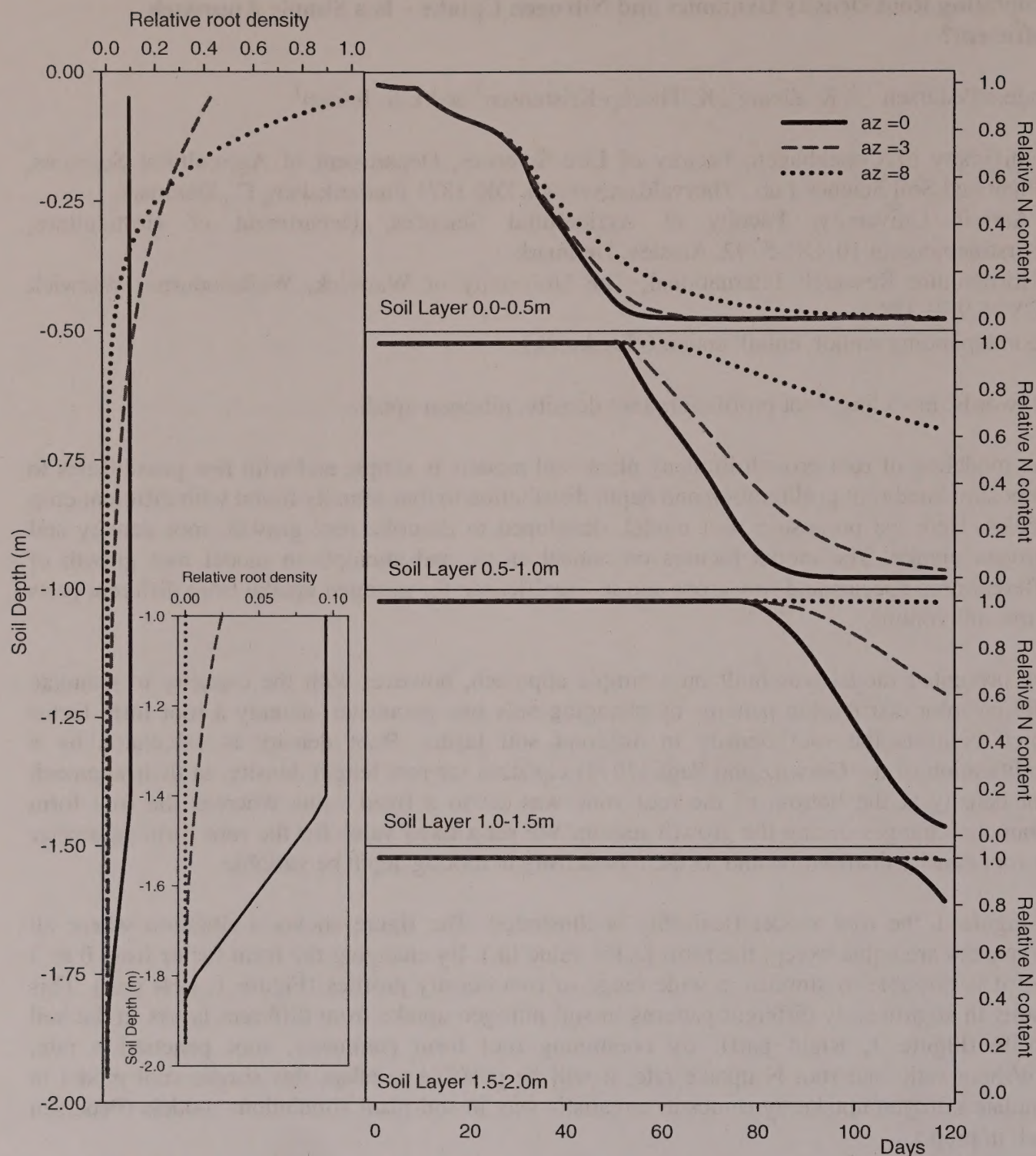


Figure 1. Simulation result from present root model where mineral content in soil was below potential nitrogen demand for the crop. Left part: Relative root density distribution in soil profile with three different form factors for a_z . All other settings are equal as root penetration rate and root biomass. Soil profile 1.0 to 2.0m with higher resolution for relative root density is shown in right part of the figure. Right part: Relative plant available nitrogen in four soil layers for three different form factors. Legend, Form factor values: Solid line (dark blue) $a_z = 0$; Short dash line (dark green) $a_z = 3$; Dotted (Dark red) $a_z = 8$.

An Approach for Predicting One and Two Dimensional Root Growth in the CROPGRO Model as a Function of Soil Properties

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Prediction of root length density with soil depth is important in crop models in order to accurately predict crop growth and N assimilation responses to soil properties, limiting soil water, and N availability. The CROPGRO model (Boote et al., 1998), as well as other DSSAT V4.0 models, currently has a root hospitality function, WR(L), as a function of soil depth that describes where root length should be grown, given that the rooting front has reached that depth and depending on the soil water status in that layer. Each crop species has its own unique soil profile for the same soil, differing only in the WR(L) values. This approach has limitations in the V4.0 release which now allows crop rotations with different crops growing on the same land unit. This requires that only one soil profile be used (thus obviating the use of different WR(L) for different crops). In addition, we are developing a new CROPGRO model version for mulch bed crops like tomato with drip irrigation in a 2-dimensional approach for which the model needs 2-dimensional root growth.

To facilitate this need, we developed a conceptual model for CROPGRO in which root growth in one dimension and/or two dimensions (with variable cell size) is predicted as a function of static and dynamic soil properties, following most of the coding strategies described by Jones et al. (1991). The rate of elongation growth of root tips (meristems) is predicted in both vertical and horizontal directions, in a given layer or in a given cell, depending on soil properties of that layer or cell. Growth into the next deeper layer or unexplored adjacent cell depends on adjacency rules. Once roots are in a given layer or cell, root prolificacy (birth of a new root tip) can occur as a probability (say 0.1 per cm of root length) and a function of root length in that cell. The root birth/prolificacy is a function of soil properties of that cell or layer (fraction available soil water, N, P, soil organic matter, Al saturation, Ca saturation). Once a new root tip is born, it can grow in elongation length just like the other root tips. This principle basically results in a relative growth rate response of roots, although limited by assimilate supply per day and translated to root length by the length to weight ratio of the roots.

Following Jones et al. (1991), we allow rate of elongation growth of root tip meristems, the birth rate of new tips, and the length/weight ratio of roots to be dependent on static factors (Al saturation, fraction exchangeable Ca, coarse fraction and qualitative pan information described in the soil file for respective layers) and on dynamic factors (soil strength, aeration, soil temperature) for respective layers or cells that vary as a function of weather and soil water status. Among the static factors, the effect of Al depends on Al saturation of the layer, the minimum Al saturation at which roots begin to be affected (relative value 1.0) and the maximum Al saturation value at which root growth is zero (0.0), the latter two values being species and cultivar-dependent. A deficiency of Ca in a given layer can also reduce root growth, defined by percent exchangeable Ca at which root growth is adequate (1.0) and the percent exchangeable Ca

at which root growth goes to zero (0.0), both values being species dependent. The coarse fraction effect declines from 1.0 to 0.0 as fraction coarse particles ($>2\text{mm}$) increases to 1.0.

The dynamic factors are computed as a function of both soil static properties and varying soil water and soil temperature in each given layer or cell. Computing the soil strength factor requires both bulk density and soil texture. There is a range from good (1.0, no limit on roots) to bad (0.0, no root growth) bulk densities at optimum soil water status, that varies with per cent sand. A bulk density factor is computed that depends on where actual bulk density is within these two ranges. Since soil strength increases as soil dries below this optimum soil water, the actual soil strength factor is computed as a function of fraction available soil water and this scaled bulk density factor. The soil aeration factor depends on the computed fraction water-filled pore space. There is a critical fraction water-filled pore space that limits growth. This critical water-filled pore space value is dependent on clay concentration. The third dynamic factor is the effect of soil temperature in a given layer on root growth, which requires the base temperature and the optimum temperature for root growth of that species.

For the rate of root "front" depth increase, Jones et al. (1991) used a species-dependent maximum rooting depth and growth-stage dependent increase in depth, where rate of increase was dependent on the minimum of "two minimums", ASF1 and ASF2, where ASF1 is the minimum of the temperature factor, Ca factor, Al factor, and the arbitrary "pan" factor, and ASF2 is the minimum of the soil strength factor, aeration factor, and the coarse fraction factor. CROPGRO uses computed photothermal days to replace the growth stage dependency, and we may need a maximum rooting depth for each species. Surprisingly, the Jones et al. (1991) functions have no dry soil water limitation on root depth increase, other than via soil strength. Rooting front progress in the current CROPGRO is dependent on soil water status of the layer itself (reduced by deficit or excess water), but is accelerated by overall plant water deficit.

For proliferation of root length within all layers or cells that already have roots in them, we will use a species-dependent shape factor as a function of depth (also N, P, and soil organic matter (SOM) of the layer), the current root length density in the layer, the minimum of all stress factors, the predicted length per unit mass for that layer, and the current assimilate supply to all roots. The shape factor will be patterned after Jones et al. (1991). With the cell and layer approach, we will have a root tip birth rate (probability of a branch per cm of root) as a function of current root length, mineral N, available P, SOM, and assimilate supply). The root tip birth sensitivity to N, P, and SOM may substitute for the shape factor above. The new and existing root tips will have a length increase computed from root length per unit dry mass factor dependent on species, soil depth, soil physical properties (ASF2), and assimilate supply. Root senescence is computed as a function of thermal time and available soil water in each layer.

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The NICOLET Model: Carbon, Nitrogen and Water in Leaves

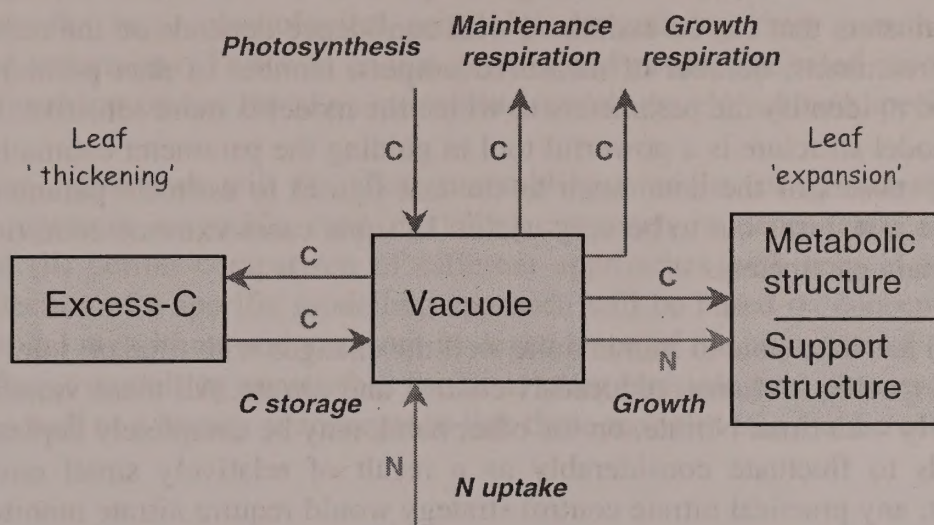
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Keywords: crop model, crop growth, nitrate in leaves, nitrogen stress

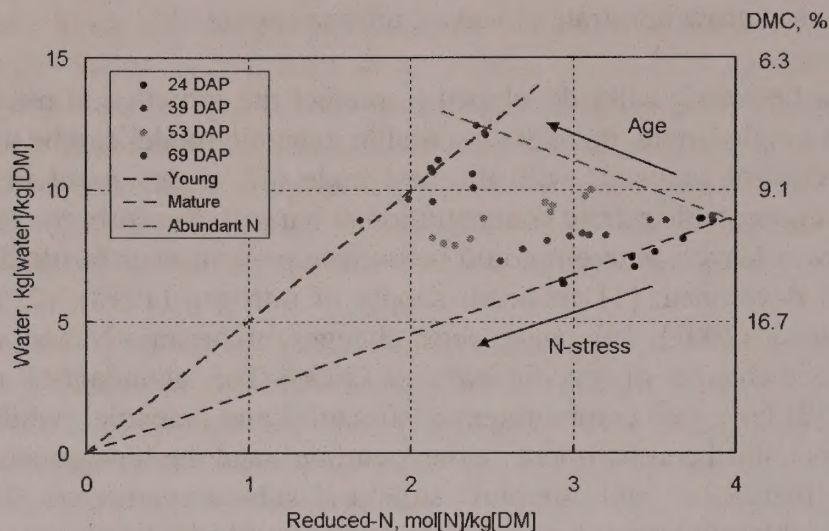
The NICOLET model has been originally developed to predict the growth and nitrate content of greenhouse lettuce. This single-organ, three-state-variable dynamic model can be used to find an optimal environmental control sequence with the best trade off, at any point in growth time, between fast growth and acceptable nitrate concentration at harvest. Recently the model has also been applied to cauliflower leaves, where it could be used to prevent over-fertilization. To-date, five versions have been developed: [1] abundant supply of nitrogen (1998), [2] mild N-stress (1999), [3] severe N-stress (2003), [4] ontogenetic changes of organic-N and water content (2004), and [5] ontogenetic changes of specific leaf area (2006). The 'abundant-N' model [1] and the 'mild-stress' model [2] have two compartments: 'structure' and 'vacuole', while the 'severe-stress' model [3] requires a third compartment: 'excess-carbon', and the 'ontogenetic' models [4] and [5] have separate 'metabolic' and 'support' structural sub-compartments. The combined model has three state variables and approximately 20 parameters (depending on version).



Two fluxes are driven by external substrate concentrations: photosynthesis and nitrogen uptake. Unlike other models, the internal fluxes are driven by availability of substance rather than by concentration gradients. Passive processes are more naturally associated with concentration gradients, while active processes are associated with 'demand' and 'supply'. In this respect, NICOLET leans towards the active view.

The main special features of the NICOLET model are [1] the osmotic balance of the 'vacuole', where nitrate and hydrocarbons play a complementary role in maintaining a constant osmotic potential, [2] the excess-carbon compartment, where 'dry' carbon compounds are stored, and [3]

the sub-division of the 'structure' into sub-compartments of different compositions. Loosely speaking, the first feature controls the nitrate concentration, the second controls the organic-N and water contents, and the third controls the ontogenetic changes. The following figure illustrates the effects of N-stress and of age on the water-to-reduced-N relationship in cauliflower (data provided by Hartmut Stützel, Institute of Horticulture, University of Hannover, D-30417 Germany). Modelling these effects requires the introduction of the afore mentioned features [2] and [3].



The number of parameters that can be estimated with confidence depends on the richness of the data set (range of treatments, number of measured outputs, number of data points). Statistical methods can be used to identify the parameters to which the model is more sensitive. In addition, understanding of model structure is a powerful tool in guiding the parameter estimation process. In particular, using subsets of the data (such as the last figure) to estimate parameter subsets, independently of the rest, turns out to be very useful. In some cases extreme conditions may be used to estimate certain parameters.

The NICOLET model has been able to mimic quite well the changes with time of: total dry matter, dry matter content, specific leaf area, reduced-N content and nitrate. All these variables, except nitrate, change slowly with time. Nitrate, on the other hand, may be completely depleted within a few days and tends to fluctuate considerably as a result of relatively small environmental changes. As a result, any practical nitrate control strategy would require nitrate monitoring every few days.

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Development of a Generic Crop Modelling Framework

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Keywords: Crop models, generic, modularity, concepts

Crop models are widely used for a range of applications. Individual models, however, are typically developed for a specific objective and are not easily reusable. Changing the objectives often requires modification of the original model structure. To overcome this limitation and enable simulation of crops and cropping systems for a range of objectives, we develop a framework that offers a coherent and structured set of concepts to (i) capture similarities and differences among crops and (ii) define the basic properties of cropping systems.

We propose an operational strategy (Figure 1) that formalizes the understanding of the system with respect to its relevant genotype (G), environment (E) and management (M) and the associated interactions (GxExM). The approach is based on the development of concepts that define the appropriate model structure depending on the objective of the simulation. These concepts relate the basic physiological principles determining crop growth to stakeholders objectives and constraints. This will enable generic and process-oriented modelling, that goes beyond traditional approaches based on monolithic models developed for a specific application.

Eventually, the framework will (i) allow assembling modules of growth and development processes to represent a specific crop modelling approach in dependence of the simulation objective, and (ii) permit comparison of different approaches with respect to the considered processes. Selection of a specific modelling approach will be based on concepts that define the appropriate model algorithms and structure in dependence of the objective of the simulation. A library of different modelling approaches for basic plant physiological processes (modules) will be available as well as a library of concepts to link these modules into a coherent crop model.

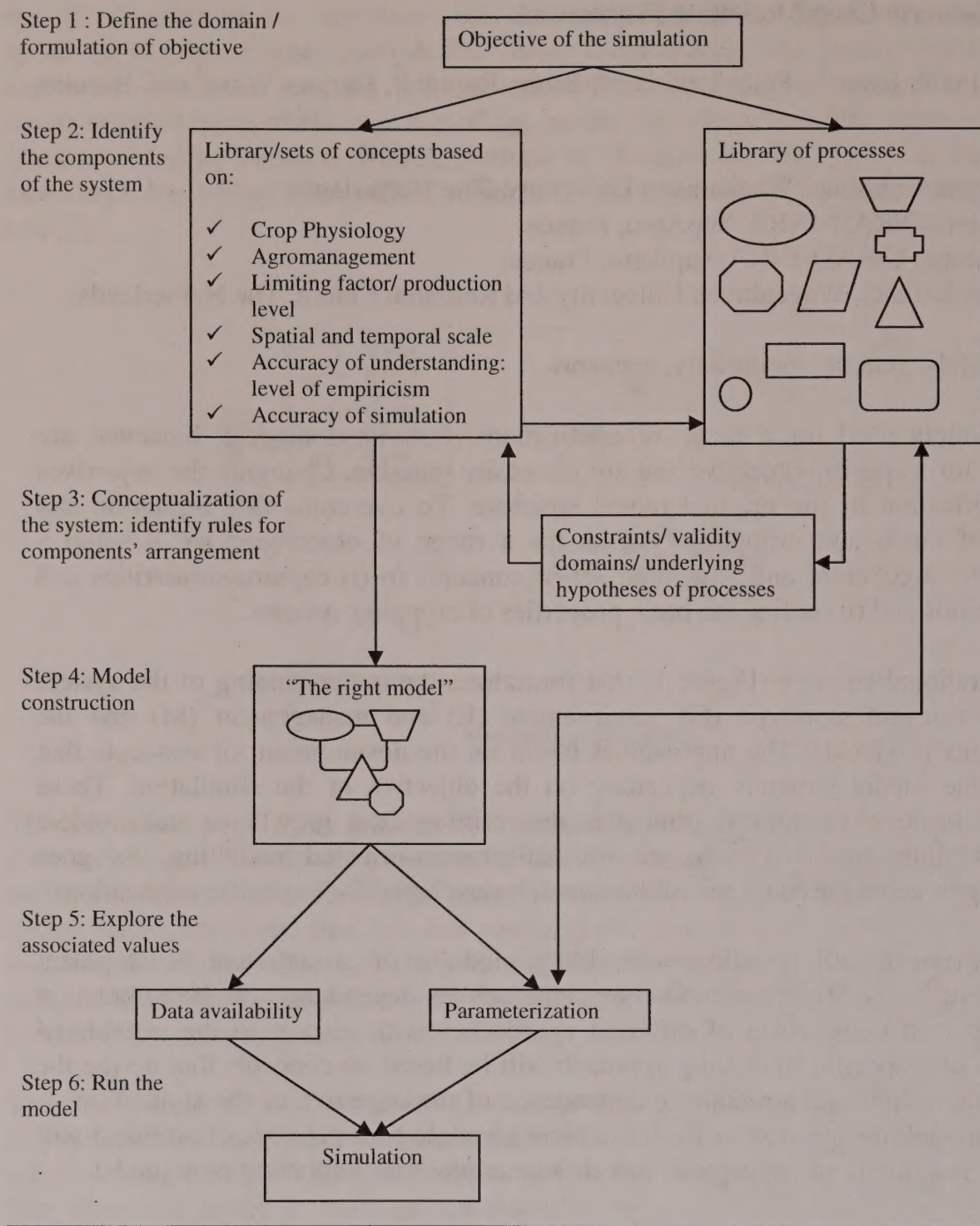


Figure 1: Crop modeling framework, an operational strategy to construct the “right model”.

Simulating Canopy Evapotranspiration and Photosynthesis of Corn Plants Under Different Water Status Using a Coupled MaizeSim+2DSOIL Model

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Keywords: corn, stomatal conductance, transpiration, drought, ABA

A coupled Maize+2DSOIL model was constructed for the purpose of simulating transpiration and photosynthesis of corn under drought stress. Two stomatal controlling algorithms (control-by-psil and control-by-[ABA]) were implemented in the coupled model. Transpiration and photosynthesis simulations were compared with measurements of corn plant under different irrigation treatments. Results showed that the coupled model was able to simulate the changes in transpiration and photosynthesis of corn plants under drought stress, and that model with stomatal controlling mechanism performed better than that without stomatal control in simulating transpiration of corn plants on drying soil. When simulating corn transpiration under drought stress, the control-by-psil algorithm performed better than the control-by-[ABA] algorithm. Reasons for these differences will be discussed. To adopt the controlling-by-[ABA] mechanism in the model, the sensitivity of stomatal conductance to leaf water potential, the ABA synthesis rate of both root and leaf should be calibrated for the specific cultivar that is under study. It was also found that the simulated photosynthesis was not as sensitive to stomatal closure as simulated transpiration. The result agreed with the differences in sensitivity of photosynthesis and transpiration to changes in stomatal closure that have been reported in the literatures. These results suggest that the coupled model not only is a valuable tool in studying corn transpiration and photosynthesis under drought stress, but it also provides a platform to implement and evaluate algorithms in studies on corn crop water dynamics and CO₂ assimilation.

Source-Limited and Sink-Limited Kernel Set: Two Complementary Approaches to Simulate Kernel Number with CERES-Maize

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CERES-Maize considers kernel set a source-limited process and establishes the number of kernels based on average plant growth rate during the lag phase after flowering. Yet the number of kernels formed by maize also depends on the timely interaction between the male and female flowers, which can limit the formation of reproductive sinks under some conditions. Failure to account for this sink-limited kernel set may contribute to simulation error under conditions that affect the dynamics of pollen shed or silking, but do not alter the crop growth rate. The first objective of this study was to develop the algorithms required to simulate sink-limited kernel set in maize. The second objective was to link these algorithms into CERES-Maize and test the model's capacity to simulate kernel number per plant under both source-limited and sink-limited conditions.

A stand-alone Flowering Model, which simulates sink-limited kernel set from flowering dynamics, was developed as a preliminary step and calibrated against kernel production in hybrid seed production fields. The Modified CERES-Maize model was developed later, linking the Flowering Model to the Original CERES-Maize. The resulting modified model was calibrated against two years of field data involving three hybrids, eight population densities, and seven nitrogen levels.

Integrating the capacity to simulate sink-limited kernel set with source-limited kernel set increased the accuracy of simulated kernels per plant dramatically. For the 13 commercial fields tested, Modified CERES-Maize decreased the average simulated error from -17.1% to +2.3%, increased r^2 between measured and simulated values from 0.767 to 0.874, and decreased simulation error indicators ME, RMSE, MSD by 85%, 40%, and 64%, respectively. This improvement was due to more accurate simulation of kernel set at plant population densities higher and lower than typically used in commercial production.

These results indicated that the Modified CERES-Maize model accounts for a much greater range of variability in the biological processes controlling kernel set.

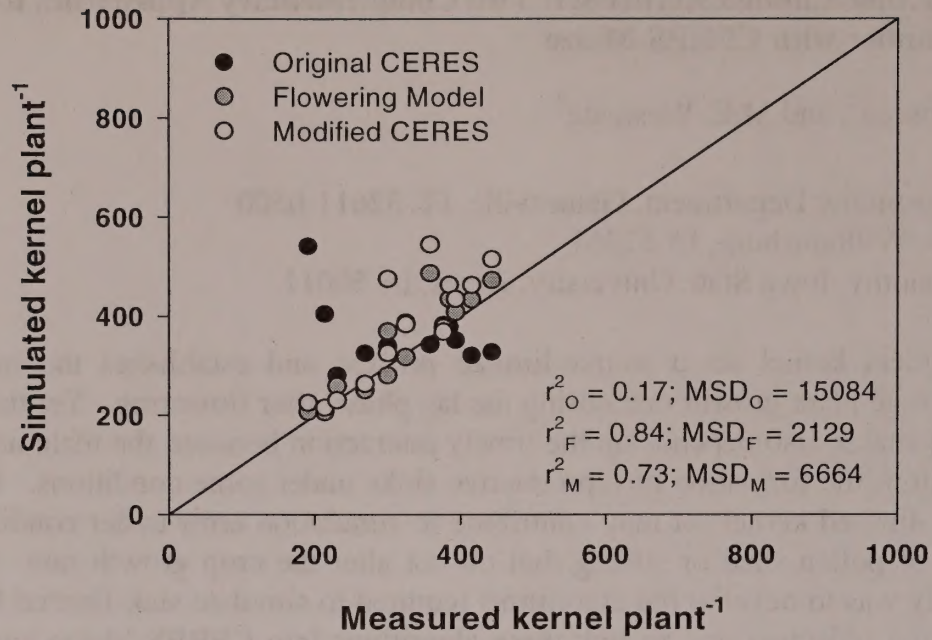


Figure 1: Comparison of measured and simulated kernel number per plant under sink-limited conditions. Simulated values were obtained using the Original CERES-Maize (O), with a stand-alone Flowering Model (F), and with a Modified CERES-Maize (M) incorporating algorithms to simulate source- and sink-limited kernel set. The Flowering Model simulates only sink-limited kernel set.

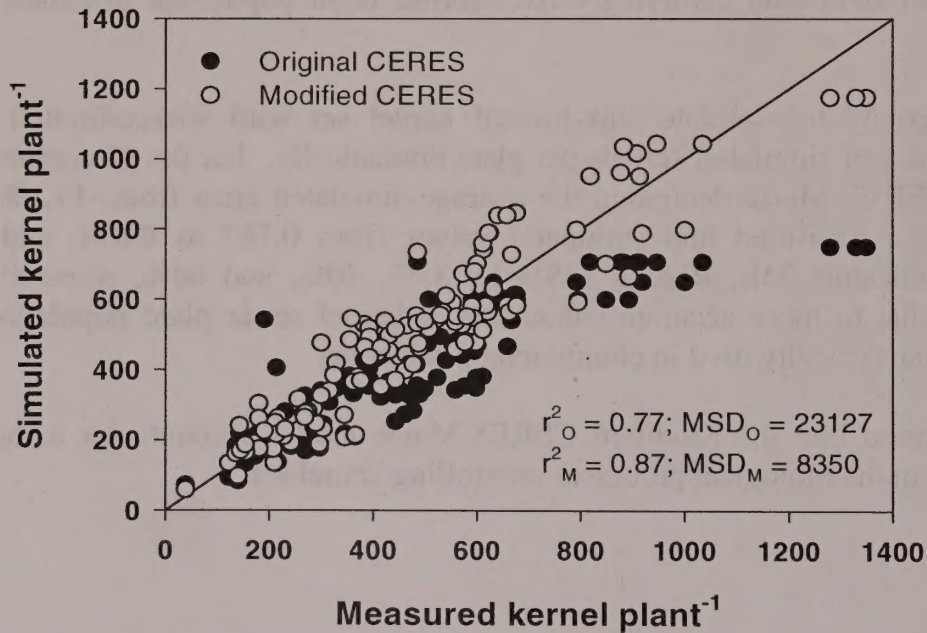


Figure 2: Comparison of measured and simulated kernel numbers per plant under a range of source- and sink-limited conditions. Simulations were obtained with the Original CERES-Maize (O), and with a modified version of CERES-Maize (M) incorporating algorithms to simulate source- and sink-limited kernel set. All evaluation data sets were included. Each data point is the average of replicated measurements; $n=127$.

Initializing Soil Carbon Models for Agricultural Systems

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Keywords: Soil Organic Carbon, Organic Carbon Pools, CENTURY, DSSAT

Initializing dynamic soil organic matter (SOM) models is an important consideration for their application in agriculture and natural systems. Most SOM models assume that total C is contained in different pools and it is important that C in each pool be known to initialize the models. In this paper, we demonstrate the importance of reliable estimates of initial pool sizes; it is not sufficient to have reliable measurements of initial total soil C. Default values of the fractions of C in each pool are usually provided by model developers, but they should not be used unless one is confident that they are reliable for the soil and cropping system or natural system being simulated. One approach to initialize the pools of C in SOM models (as well as total C if it is not measured) has been suggested by model developers. In this procedure, the model is simulated for hundreds or thousands of years under the same conditions to arrive at steady state values. However, agricultural systems change over relatively short time periods, sometimes every 5-10 years, and soil C would not reach steady state conditions. Thus, there is a need to evaluate different methods for estimating pool sizes, given that reasonably accurate measurements can be made for total soil C.

Century is an ecosystem model that simulates on a m² scale the dynamics of soil organic carbon and nitrogen. The model has three C pools in each of several soil layers (active, intermediate and passive), above and belowground litter pools, and a surface microbial pool which is associated with decomposing surface litter. These pools are theoretical compartments based on their different rates of SOM decomposition more than on measurable carbon ratios. In the model, SOM1, active soil organic matter, represents soil microbes and has a turnover time constant of several months to a year depending on the environment and soil texture. SOM2, intermediate soil organic matter, includes resistant plant material derived from the structural plant tissue and soil-stabilized microbial products derived from the active and surface microbe pools. It has a turnover time constant of around 8 to 20 years. SOM3, passive soil organic matter, is resistant to decomposition and includes physically and chemically stabilized SOM with a turnover time constant of around 200 to 500 years depending on conditions. There is only one analytical technique providing good estimates of one of the three fractions (SOM1), the fumigation technique where the total active C pool is ca. 2 to 3 times the live microbial biomass level.

Since the initial values of these fractions have a major impact on simulated results, procedures are needed to initialize these fractions. The objective of this work is to develop procedures to initialize SOM1, SOM2, SOM3 fractions, given that initial total soil C is measured for a field to be simulated. We used the Decision Support System for Agrotechnology Transfer (DSSAT v4.02) to simulate crop sequences (maize-fallow), with the Century model option. We evaluated 12 soil textural classes, without nitrogen application, automatic irrigation and differentiating two soil layers: 0-20 and 20-40cm depth. Two procedures were compared with the use of the default value. In the first procedure we ran a sequence of 20 years starting with the measured total C and default SOM fractions. The SOM fractions obtained at the end of this sequence, along with the measured soil C, were used to initial C and SOM fractions to repeat the 20 years of simulations. This procedure was repeated five times for a total of 100 years. In the second procedure, the maize-fallow rotation was simulated for

100 consecutive years starting with measured total C and the default SOM fractions. In each case, the initial total organic carbon was the same value. The SOM fractions obtained from the two procedures and the default fractions were compared by running DSSAT-Century with the same crop-rotation for another sequence of 20 years with a loamy sand soil. Three cases were simulated, SOM fractions initialized with default values and initialized with the two SOM fractions obtained after 100 years of simulation with both methodologies. In each case, except for the default fractions, SOM fractions nearly stabilized in each layer after 100 years. The total organic carbon values (Fig.1), obtained using the default SOM fractions, continued to decrease after 20 years and was considerably lower than values obtained with the other two procedures. The total organic carbon at the end of the 20-year maize-fallow rotation was 12% lower than that obtained by running the model five times iteratively for 20 years each and 10% lower than organic carbon obtained by running the model with the 100 year continuous simulation.

These differences could have major influence on crop yield due to the differences in nitrogen released during SOM decomposition. When default SOM fractions were used, total organic nitrogen remaining (Fig.2) after 20 years of maize-fallow rotation was 25% lower than nitrogen remaining after running the model with the 20year time step and 23% lower than the organic nitrogen obtained running the model with the 100 year continuous simulation approach. Thus, more N would become available from SOM decomposition if carbon in the soil was distributed according to the default SOM fractions (by about 600 kg/ha in this example) and indirectly affect the mineral nitrogen available for the crop dry matter production and yield. These results are consistent with observations from long term experiments, which demonstrate that SOM fractions can change considerably over time in response to agricultural practices.

We concluded that much more attention needs to be given to initializing SOM models for agricultural applications that change over relatively short periods of time. It may be possible to develop a practical method for initializing soil C pools through further analysis of the approaches summarized here. More work is needed in which the models are evaluated using measurements from long term crop rotation experiments to help ensure that methods for initializing the models are accurate.

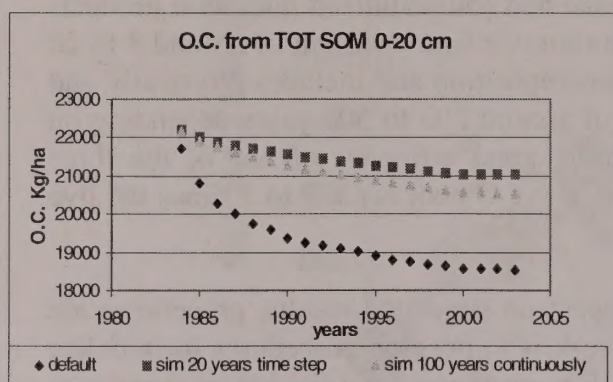


Fig.1 Organic Carbon in 0-20cm using 3 different SOM fractions, each starting with the same total soil C value for a Loamy sand soil

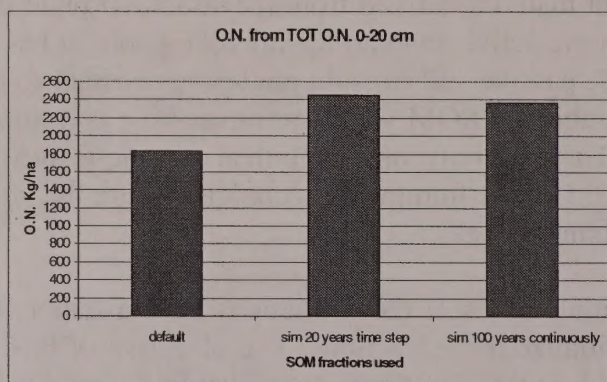


Fig.2 Organic Nitrogen in 0-20 cm remaining after 20 years for the 3 different SOM fractions, each starting with the same total soil C value.

Simulated Nitrogen Management Effects on Soil Organic Carbon Fractions

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Keywords: Nitrogen management, Soil Organic Carbon Pools, CENTURY, DSSAT

The DSSAT-Century model has three pools of soil organic carbon that must be initialized when the model is applied to study cropping systems. Even if total soil carbon levels are measured, the fraction of this carbon in each pool has a major effect on soil carbon dynamics and thus on crop growth dynamics, especially in low input agriculture. The Century model has two options for default soil organic carbon (SOC) fractions, one for grasslands and one for cultivated soils. The SOC fractions vary with time and are affected by soil texture and management, which in turn can determine the long-term trends of organic carbon. The objective of this work is to study the effects of soil-crop management over a time period of 20 to 100 years on simulated SOC fractions for various soil textures using the DSSAT-Century model. This information could help determine a robust way to initialize SOC fractions when using this model. In contrast to running the model for thousands of years to initial SOC fractions in natural systems, cropping systems are not likely to remain the same over long time periods, and thus steady state of the slowly decomposing stable SOC pool (SOM3 in Century) would not be reached. However, a near steady state may be reached in the more rapidly decomposing pools that have time constants on the order of 3 to 10 years.

Twenty years of weather data and 12 soil data files from Tifton, Georgia, were used with DSSAT v4.02 to simulate a maize-fallow crop sequences using the Century SOC model option. Management treatments were high nitrogen (306 kg/ha) and no nitrogen (N0), with residues incorporated at the end of each season, and automatic irrigation to demonstrate a range of pools that may occur after initializing the SOC pools the same for each management and soil texture. The twelve soil textures varied in sand content, ranging from ??? to ??? percent. Soil carbon results were differentiated for two layers: 0-20 and 20-40 cm depth.

For the stabilization process of the initial SOC fractions values in all soil classes, management, and soil depth we used a 20-year time step simulation approach. We ran a sequence of 20 years starting with the measured total C and default SOC fractions to estimate an approximate steady state. This was done in an iterative fashion using 20 years of simulations in each of five runs. The same total soil C was used to initialize total soil C for each 20 year sequence, but the SOC fractions obtained at the end of each sequence was used to initialize SOC fractions for the next 20 additional year simulation. This procedure was repeated five times for a total of 100 years after which the SOC fractions reached values near to steady-state.

Sandy loam soils, for example, cultivated with maize and high N fertilization resulted in higher crop growth and biomass production and more C incorporated into the soil relative to the no-N treatment. By constraining initial SOC to measured values in each 20-year sequence, differences in SOC fractions occurred, but not in total C. The trends in SOM2 (pool of slowly decomposing

SOC) and SOM3 (pool of stable or passive SOC) fractions (Fig. 1-2) are shown as an example. In both treatments, SOM2 decreased and SOM3 increased over time relative to default values from Century. However under high-N management, the changes in SOM2 and SOM3 fractions were small relative to the no-N management. Since soil fertility is more dependent on SOM2, the higher SOM2 fraction in the high-N implies faster SOC decomposition and release of N for subsequent crop production relative to the no-N treatment.

In conclusion, soil textural classes and soil-crop management affect the SOC fractions and thus mineralization. We are developing algorithms to initialize SOC fractions for each soil textural class as a function of management for practical applications. This approach will require field testing in to evaluate its reliability in initializing the SOC pools for the DSSAT-Century model when total SOC is measured.

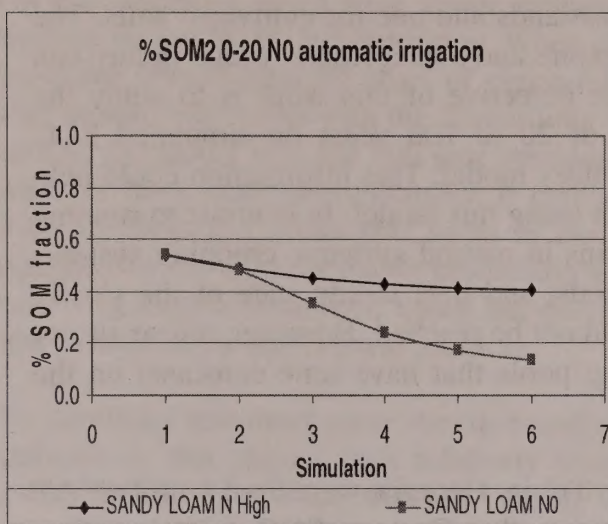


Fig.1: SOM2 trend in a Loamy Sand soil with two N-management levels over 100 years of simulations

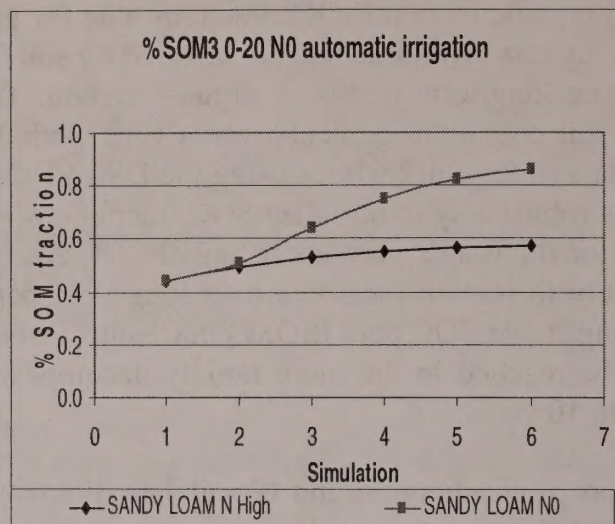


Fig.2: SOM3 trend in a Loamy Sand soil with two N-management levels over 100 years of simulations

Simulating Fresh Mass Yield and Potato Tuber Size Distribution with CSM-SUBSTOR

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CSM-SUBSTOR (Griffin et al., 1993) is a potato simulation model that is used extensively around the world. It simulates crop growth, development, and tuber dry mass yield using a minimum set of weather, soil, genetics, and management inputs. The model calculates the beginning of tuber growth (tuber induction) as a function of day length, soil temperature, and the most limiting stress associated with soil water or nitrogen. Tuber induction response is mediated by a cultivar specific coefficient (P2). After tuber initiation, total tuber growth is computed as a function of assimilate supply, temperature, photoperiod, and limited supply of soil water and nitrogen. Cultivar specific coefficients control the potential tuber growth rate ($G3$, $\text{g m}^{-2} \text{d}^{-1}$), and the effective beginning of tuber growth. Results are shown daily as tuber dry mass (kg/ha) and as tuber fresh mass (Mg/ha), assuming a constant tuber dry mass concentration of 20%.

Potatoes are marketed on a fresh mass basis with quality classes determined by tuber diameter. Tuber diameter is the largest dimension normal to the longitudinal axis of the tuber (USDA, 1991). Other potato standards are based on classes determined by tuber weights. CSM-SUBSTOR and other potato models do not simulate distribution of tuber sizes. The objective of this work was to improve the simulation of tuber dry mass concentration and to develop a dynamic distribution of tuber sizes that can be used to calculate size quality classes based on user-input breakpoints for classes.

We used the model code of CSM-SUBSTOR as distributed with the Decision Support System for Agrotechnology Transfer (DSSAT v4.0). The new model functions were calibrated using data from one experiment planted in O'Brien, Florida in 2001, using two N levels (normal and low N) as treatments. Tuber dry mass concentration showed an exponential increase through the season. Tuber size distribution showed a seasonal trend of increasing average tuber size and number of classes. Simulated growth, phenology, and yields were evaluated using an experiment planted in O'Brien, Florida in 2002, with similar treatments. Other experimental data included with DSSAT from Australia, and the states of New York and Oregon were also used to test the model. The patterns of simulated potato size distribution were compared with literature reports (McRae et al., 1986; Travis, 1987; Struik et al., 1990, Fig 1).

Our simulated results of growth, phenology and yield, obtained with the new model were closer to measured values than those obtained with the original model. Simulated yield size distributions followed a pattern similar to various reports in the literature (McRae et al., 1986; Travis, 1987; Struik et al., 1990).

The general approach followed to simulate fresh mass yield and harvestable product size distribution can be applied to other vegetable crops.

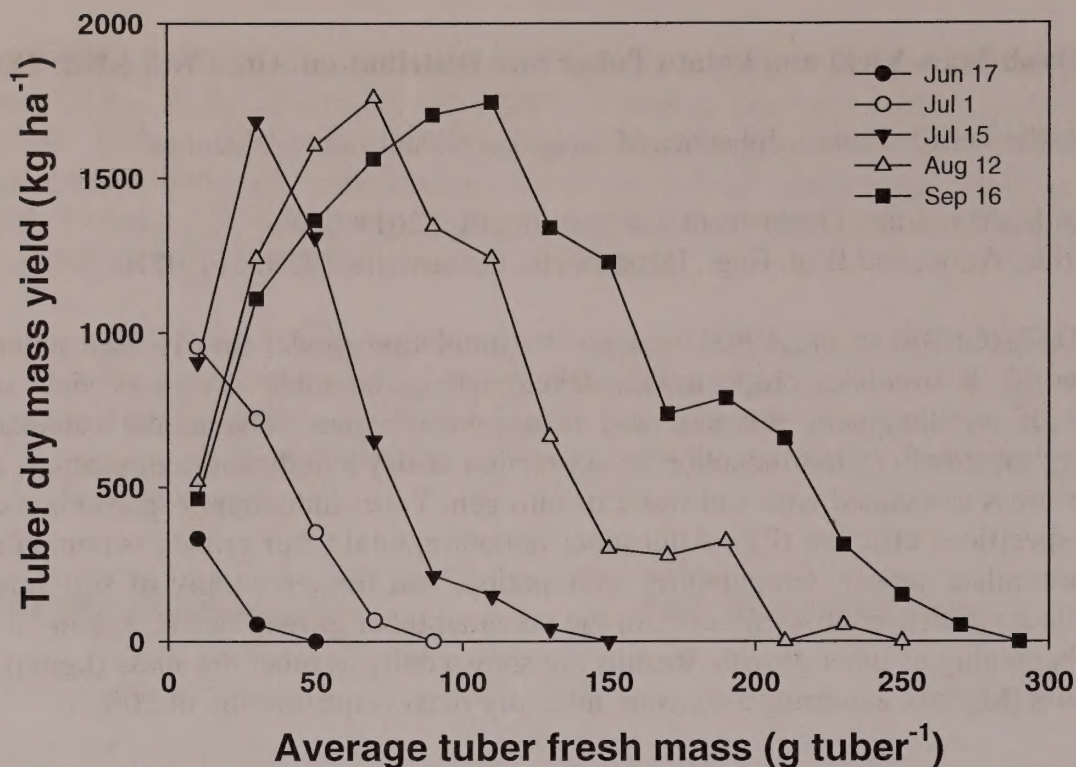


Figure 1: Seasonal tuber yields of various tuber-size classes (Struik et al., 1990).

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Regression-Based Analysis of Modeled Responses to Water Deficits in Wheat and Common Bean

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A key issue in modeling crop response to water deficits or other environmental factors is how best to assess model performance. Qualitatively reasonable responses to irrigation or precipitation regimes are easily shown but simple comparisons of observed vs. simulated data often provide little information beyond the trivial conclusion that growth increases with available soil water. Multiple regressions have been used to extend conventional comparisons of observed vs. simulated responses by including the effects of locations, cultivars, environmental conditions, and management (White et al., 2007). These statistical techniques can also be easily applied to comparisons of modeling approaches and appear to be readily extended to evaluating modeled responses to soil water deficits. Issues arise, however, relating to the non-linear responses of crops to soil water availability and to problems in comparing water regimes across experiments. The goal of this study was to explore the use of multiple regression for analyzing responses of crop growth and development to varying soil water levels using the Cropping System Model (CSM v4.0.2) as provided in DSSAT 4.02 (Hoogenboom et al., 2004).

Simulations were conducted for bread wheat (*Triticum aestivum*) and common bean (*Phaseolus vulgaris*) experiments that comprised different locations, cultivars, and irrigation regimes. Following the approach of French and Schultz (1984), effects of different irrigation levels were examined using cumulative evapotranspiration (ET) as estimated by the model.

Regressions using two irrigation studies with common bean conducted at Gainesville, FL illustrate the approach as applied to grain yield (Table 1). In 1985, four cultivars were tested under irrigated and rainfed conditions, and in 1986, two cultivars were grown with four irrigation regimes plus a rainfed control. In the first regression, the model is seen to explain a large portion of the variation ($r^2 = .77$, $p < .01$), but this provides no information on whether the explained variation is due to effects of irrigation, cultivars or years.

The second regression tests sequential effects of cumulative irrigation as reported for the experiments, cumulative evapotranspiration (ET) as estimated by the model, and simulated grain yield (Table 1). Irrigation alone explains 34% of the variation in grain yield, as indicated by the portion of the total sums of squares (SS). ET accounts for an additional 46%, indicating that the modeled crop water balance explains an even larger portion of yield differences. Including an effect of grain yield explains an additional 6% of variation ($P < 0.05$).

Among additional queries one might pose is whether the success in predicting yield involves mainly ET and biomass accumulation or whether the model represents differences in partitioning to grain that relate to the irrigation regimes. An indirect test is provided by first determining how much variation is explained by simulated crop dry weight at maturity and then testing whether simulated grain yield explains further variation (Table 1). The results show that crop dry weight explains most of the modeled variation in grain yield.

Similar analyses are presented for wheat. Tests are made for location x year effects, effectiveness of alternate model subroutines, and prediction of time series data showing autocorrelation.

Table 1. Analyses of variance for linear regressions of grain yield (kg ha^{-1}) of common bean in two irrigation experiments grown at Gainesville, FL. Effects are tested sequentially, so the sums of squares for successive variables reflect changes in sums of squares attributable to the effect of each additional variable. IR = cumulative irrigation; ET = cumulative ET; CDW = simulated above ground crop dry weight at maturity.

Source	DF	SS	% Total SS	F	R ²
<i>Basic test of observed (Y) vs. simulated data (S): $Y = a + b S$</i>					
Simulated grain yield	1	8422109	77	53.6***	.77
Error	16	2515973	23		
<i>Testing whether ET and simulations explain variation after irrigation is accounted for: $Y = a + b IR + c ET + d S$</i>					
Cumulative irrigation	1	3699476	34	33.2***	.86
Cumulative ET	1	5020544	46	45.1***	
Simulated grain yield	1	659767	6	5.9*	
Error	14	1558293	14		
<i>Testing whether simulated crop dry weight explains most of variation in observed yield: $Y = a + b CDW + c S$</i>					
Simulated crop dry weight	1	8033564	73	48.0***	.77
Simulated grain yield	1	391750	4	2.3	
Error	15	2512767	23		

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Agricultural Productivity and Climate Change: Challenges and Opportunities

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Documented and projected changes in atmospheric carbon dioxide are likely to alter agricultural productivity in two ways: directly, by supplying additional carbon for photosynthesis; and indirectly by altering surface temperatures with subsequent effects on where crops can grow. In this overview on the impact of CO₂ and climate change on agriculture, I present data from a number of sources that document the impact of CO₂/climate on crop responses, intra-specific variability in crop responses to CO₂/climate as well as weed biology, crop weed competition and invasive weeds. In addition I will discuss a growing number of studies that indicate how CO₂/climate may have significant effects on the chemical, biological and mechanical control of weeds in the future. I hope to elaborate on current USDA efforts in this area and encourage potential collaborations on investigating these areas of research in the near future.

The first part of the paper is devoted to a general discussion of the problem of the existence of a solution of the system of equations (1) for arbitrary values of the parameters α and β . It is shown that the system has a solution for arbitrary values of the parameters α and β if and only if the matrix A is nonsingular. The second part of the paper is devoted to a detailed study of the properties of the solution of the system of equations (1) for arbitrary values of the parameters α and β . It is shown that the solution of the system of equations (1) for arbitrary values of the parameters α and β is unique and depends continuously on the parameters α and β . The third part of the paper is devoted to a study of the properties of the solution of the system of equations (1) for arbitrary values of the parameters α and β . It is shown that the solution of the system of equations (1) for arbitrary values of the parameters α and β is unique and depends continuously on the parameters α and β .

Cotton Growth, Development and Physiology as Affected by Nitrogen Nutrition and Elevated Carbon Dioxide: Developing Functional Algorithms for Modeling

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As humanities continue to cause perturbation in the atmosphere, cotton crops in the 21st century are expected to grow in dramatically different environments than today. Currently, atmospheric carbon dioxide concentration is about $380 \mu\text{L L}^{-1}$, and there is general agreement among climatic and atmospheric scientists that the atmospheric carbon dioxide could be in the range of 540 to $970 \mu\text{L L}^{-1}$ sometime in the middle or latter part of the 21st century. The rising levels of atmospheric carbon dioxide concentrations are expected to affect cotton growth and development. Two experiments were conducted to quantify the effects of atmospheric carbon dioxide concentration and nitrogen nutrition on cotton growth and development. In Experiment I, cotton plants grown in 12-L pots at two CO_2 levels (360 and $720 \mu\text{L L}^{-1}$) were subjected five N treatments from 17 to 32 days after emergence in controlled plant growth chambers in a nearly natural environment. The temperature in all the chambers was maintained at $30/22^\circ\text{C}$, day/night. Growth rates of stems, leaf area, node development and leaf photosynthesis measured frequently were regressed against leaf N to develop functional algorithms. The second experiment was seeded in one meter deep soil bins to understand seasonal dynamics of canopy photosynthesis in relation to nitrogen nutrition and elevated carbon dioxide for the whole growing season. In this experiment, the chambers were filled with fine sand, and seeds were placed 10 cm apart in three 66-cm rows. As in Experiment I, the temperature in all chambers was maintained at $30/22^\circ\text{C}$, day/night. During the whole season, two carbon dioxide treatments, 360 (ambient) and $720 \mu\text{L L}^{-1}$ (elevated) were applied during the daylight hours. A half-strength Hoagland's nutrient solution was applied daily to each growth chamber via a drip irrigation system. At initial flowering, 53 days after emergence, the units were leached with water, and one unit was supplied nutrients with no nitrogen in each of the carbon dioxide treatments while the other chambers were supplied with a half-strength Hoagland's nutrient solution. During the experimental period, canopy photosynthesis was measured by a mass balance approach. From the photosynthetic light responses curves, canopy light utilization efficiency and canopy conductance were estimated each day in all treatments. At weekly intervals, topmost fully expanded leaves were used to determine leaf N by micro-Kjedahl digestion. To obtain relationships between leaf nitrogen and the measured parameters, daily leaf N was required. Leaf N data from the weekly measurements were regressed against days after treatment to obtain daily leaf N data using curve fitting procedures.

Results from Experiment I show that the relationships between leaf N concentrations and the measured growth and photosynthetic rates were altered by both N and CO_2 levels; the responses to N, however, were much greater than carbon. Growth rates of stems, leaf area expansion and photosynthesis were greater at all levels of N concentrations for plants grown in the elevated CO_2 than at the ambient CO_2 level. Node addition rates were not responsive to CO_2 , but decreased with increased N stress. Growth and developmental rates expressed as fraction of the maximum observed at optimum N concentration were not much different between CO_2 levels, and declined with lower N levels. Among the processes measured, leaf growth was more

sensitive and responsive to leaf N deficiency followed by stem extension, photosynthesis and leaf developmental rates.

Results from Experiment II show that the N concentration in the leaves was decreased by 11% on a dry weight basis by CO₂-enrichment. These reductions occurred despite continuous application of relatively high rates of N and other nutrients. Carbon dioxide enrichment significantly increased canopy photosynthesis and the response to elevated CO₂ sustained throughout the growing season. The relative photosynthetic response to elevated CO₂ (photosynthesis at 720/360 $\mu\text{L L}^{-1}$ CO₂ calculated at 1200 $\mu\text{mol mol}^{-1}$ PPFD by regressing daily canopy net photosynthesis as a function of solar radiation) was 29% more during the boll-filling period. Like in many C₃ plants, these higher photosynthetic responses to elevated CO₂ were primarily due to greater flux of carbon through the photoreductive cycle and suppressed photorespiration. Canopy photosynthetic nitrogen use efficiency was higher for plants grown in elevated CO₂, and the relative response was greater at low to medium leaf N levels than at optimum leaf N. The changes in physiological and biochemical processes appear to alter foliar N concentrations required for maximum photosynthetic rates (90% of the maximum) and thus the productivity of cotton. Critical N concentration in the leaves was 3.1% for the ambient atmospheric CO₂ conditions. Elevated atmospheric CO₂ concentration decreased this critical N by 21%. Canopy conductance was lower at elevated CO₂ but increased linearly with increases in leaf N concentrations in both CO₂ treatments. Canopy light utilization efficiency was greater at elevated CO₂ compared to ambient conditions. The response to leaf N concentrations was not different at various N levels except at very low N concentrations.

In summary, as the atmospheric CO₂ rises, fertilizer requirements for growing cotton will need reassessment. The current critical foliar nutrient concentration may not be valid in the future climates. Critical concentrations of leaf N appear to vary with CO₂ environment and will need continuous reassessment as CO₂ in the atmosphere continues to rise due to human activity. Lower concentrations of N in the foliage have potential implications in agriculture, affecting C/N ratios. Foliar nutrient status not only affects insect biology and feeding rates, but also soil biota. Also, litter decomposition and mineralization are expected to be slower and stubble retention longer. The positive aspect of rising levels of atmospheric CO₂ is that photosynthesis and thus productivity and yield of cotton are likely to increase. This is good news to all cotton farmers. Also, the greater photosynthetic nitrogen use efficiency at low to medium leaf N concentration may benefit resource-poor economies more than resource-rich economies as atmospheric CO₂ continues to rise. In addition, the functional algorithms describing various growth and developmental processes of cotton in response to N concentration at ambient and elevated CO₂ will be useful to improve cotton models to more accurately predict crop growth and development either in the present or in the future changing production environments.

Regulation of Active and Passive Nitrogen Uptake in Response to CO₂ and Nitrogen Application Rate

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Nitrogen is one of the most important nutrients for plant growth and often the most limiting one. In order to support high growth rates, the plant must have enough nitrogen to form structural components and photosynthetic material from assimilated carbon. As a result, the interaction between nitrogen application rate and carbon assimilation strongly affects growth and development processes. Without enough nitrogen, the plant becomes limited in the amount of carbon it can assimilate and cannot reach its growth potential. Plants generally obtain their nitrogen via their root system. Active and passive uptake mechanisms are important for nitrogen uptake in plants. Active uptake includes nitrogen entering a plant via a diffusive flow process in the roots. This process is believed to be controlled by the plant and depends on plant demand for nitrogen. Passive uptake includes nitrogen that enters the plant as mass flow mixed with water that enters the root system in the transpiration flow. This is controlled by environmental factors such as vapor pressure deficit, radiation and CO₂ concentration. It has been shown that nitrogen uptake is not always related to transpiration indicating a strong role for active uptake. Little is known, however, about how the plant regulates nitrogen influx for active uptake processes or the relative importance of the two processes as nitrogen content and carbon assimilation rate varies. Since the need for nitrogen is dependent on carbon assimilation, it seems likely that nitrogen demand could be dependent on carbon assimilation rate. It has been shown that total N uptake is proportional to carbon assimilation in tall fescue, but only at medium to low light levels (GASTAL and SAUGIER, 1989). It appears that at higher light levels, additional C is being stored in the plant and not incorporated into photosynthetic or structural materials, reducing the proportion of N required. There is still limited information on how the total uptake is proportioned between active and passive components. The goal of this study was to use a simulation model to compare different theories regarding nitrogen uptake and compare the results, on a qualitative level, to results from an experiment with potato. The experiment used two levels of CO₂ and five levels of N.

Two consecutive experiments were carried out in the summer of 2005 in six sunlit, controlled environment plant growth chambers with six nitrogen application rates and two levels of CO₂, 740 $\mu\text{mol mol}^{-1}$ and 370 $\mu\text{mol mol}^{-1}$. The six nitrogen treatments were 2, 4, 6, 8, 11 and 14 $\mu\text{mol L}^{-1}$ of N. Whole plant canopy photosynthesis, light interception, and transpiration were measured at 5 and 15 minute intervals. At the end of the season the plants were separated into leaves and

stems of individual components, and measured for area, weight, carbon, and nitrogen contents. The two dimensional water and solute transport model 2DSOIL with a simple plant model was modified to simulate active and passive transport of N. We used a Michaelis-Menten (MM) type model to simulate uptake as a function of nitrogen concentration at the root surface and surrounding soil. Concentration at the root surface was determined by the carbon assimilation rate and soil N concentration. Simulations were carried out using a range of boundary and atmospheric conditions from the nitrogen X CO₂ experiment with potato.

The nitrogen contents in all N treatments were lower at elevated CO₂ than at ambient and the carbon content higher. Higher nitrogen applications increased the rate of secondary and tertiary branch growth in both CO₂ treatments. Elevated CO₂ appeared to enhance branching, especially at higher N levels. Nitrogen uptake and effects on partitioning appear to be related to carbon assimilation rates and the C/N ratio is an important factor. The experimental data showed that nitrogen (N) uptake varied with carbon assimilation rate and the mean C/N ratio of the plant. The C/N ratio varied with N application rate. Total measured N uptake varied from 20 to 90 mg N per plant per day during the exponential growth period and that passive N uptake was a small component of total N uptake but increased linearly as N concentration in the soil and transpiration rate increased. The active uptake rate increased asymptotically with nitrogen concentration leveling off at about 6 to 8 $\mu\text{mol L}^{-1}$ N. The asymptotic behavior was related to the decline in demand for N as the N rate increased and carbon assimilation rate also reached a plateau. The simulated data showed similar relationships. These results suggest that active uptake is an important component of total N uptake and that the C/N ratio and carbon assimilation rates can be used to estimate N demand.

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Responses of Grain Sorghum to Short Episodes of Water Deficit and/or High Temperature Stress: Challenges and Opportunities to Crop Models

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Keywords: water deficit, drought, high temperature stress, seed-set, seed yield.

Water deficit (drought) and high temperature (heat) stress are among the most important yield limiting factors for many crops across the globe. It is predicted that crops in future climates are more likely to experience short episodes of severe drought and/or high temperature stress. Sorghum grown in semi-arid regions is often exposed to drought and high temperature stress during reproductive development. The reproductive phase of crop development is more sensitive to environmental stresses when compared to vegetative phase. However, there is a lack of quantitative data on impact of short episodes of drought or high temperature stress and relative sensitivity of different stages of reproductive development to these stresses. The objectives of this research were (a) to quantify the impact of short episodes of drought or high temperature stress on physiological, growth and yield processes of grain sorghum; and (b) to identify most sensitive stages to drought and/or high temperature stress during the reproductive development of grain sorghum.

Two experiments were conducted to understand the responses of sorghum to drought and high temperature stress. The first experiment (Experiment 1) was conducted to quantify the impact of drought stress during reproductive development. Three grain sorghum hybrids were grown in greenhouse and plants were exposed to four treatments (fully irrigated control; drought stress from boot leaf emergence to flowering; drought stress from flowering to seed-set; and drought stress from seed-set to mid seed fill). The duration of stress was about 15 days for each treatment. Stress was imposed by withholding the water for that period. After the stress period, plants were fully irrigated. There were 12 replicated pots randomly arranged for each treatment. All plants were harvested at maturity. Data on phenology, stomatal conductance, leaf photosynthesis and chlorophyll fluorescence were measured. At final harvest, data on vegetative (plant height, leaf numbers, tiller numbers, leaf area, dry weights of leaves and stems) and reproductive (number of branches per panicle, number of filled seeds, percent seed-set [proportion of filled to total reproductive sites] and seed dry weights) traits were measured. The results from this experiment showed that most traits were influenced by drought, but not by interaction between hybrid and drought. Leaf photosynthetic rates were decreased by 26% across all drought treatments. Similar effects were also observed on stomatal conductance and chlorophyll fluorescence. Overall, drought stress during flowering caused maximum reduction in percent seed-set, while there was no significant decrease in seed-set when stress was imposed during panicle emergence or after seed-set. Seed dry weights were significantly decreased by 14, 63 and 43% when drought was imposed during panicle emergence, flowering or early seed-filling period, respectively. Drought significantly influenced plant growth traits. Drought during booting or flowering decreased plant height. Leaf and stem weights were significantly lower when drought occurred during panicle emergence and seed-filling, suggesting mobilization of

stored resources to seeds. In contrast, high leaf and stem weights observed when stress occurred during flowering were due to lower sink strength (sink-size) due to lower seed-set. Our conclusions from this experiment are (a) drought stress at flowering resulted the lowest seed-set and seed yields, when compared to stress at other developmental stages; (b) drought caused significant changes in resource allocation depending upon timing of stress and sink strength; smaller sink-size (seed-set) increased allocation to vegetative parts, while larger sink size decreased allocation to vegetative parts and/or mobilized resources from vegetative to reproductive parts.

The second experiment (Experiment 2) was conducted to quantify the impact of short episodes of high temperature stress on sorghum. One gain sorghum cultivar (DeKalb 28 E) was grown in controlled environment indoor growth chamber at daytime maximum/nighttime minimum temperature of 32/22°C until 30 days after sowing (DAS) under fully irrigated conditions. Starting 30 DAS, plants were grown either at 32/22°C (optimum temperature, OT), or at 40/30°C (high temperature, HT), or reciprocally transferred at 10 d intervals between OT to HT regimes and vice versa, until 80 DAS. Transferred plants remained in the new temperature regime for 10 d, before being returned to their original temperature regimes. All plants were fully irrigated throughout and harvested at maturity (125 DAS). Data collection procedures were similar to those mentioned for Experiment 1. The results from this experiment showed that high temperature stress significantly influenced phenology, growth and yield traits. Continuous exposure to high temperature during reproductive phase delayed time to panicle emergence and flowering. High temperature significantly decreased plant height, but not leaf or leaf dry weights. Exposure to 10 d of HT stress significantly decreased percent seed-set. Maximum reduction in percent seed-set and seed yield occurred when plants were exposed to HT during flowering, followed by when stress occurred 10 d prior to flowering. There was no influence of HT stress on seed-set after flowering. Seed yield were decreased due to stress during both pre-flowering and post-flowering stages. Lower seed yields during pre-flowering and flowering stages were due to lower seed-set. Whereas, lower yield during post-flowering stages were due to decreased seed-size. Seed yields were decreased to a greater extent when stressed at early stages of seed-filling compared to later stages. We conclude from this experiment that (a) HT stress delayed and/or inhibited panicle emergence; (b) periods of flowering and 10 d prior to flowering were most sensitive to HT stress causing maximum reduction in seed-set (seed-numbers) and seed yield; and (c) seed yield losses during post flowering stages were mainly due to decreased seed-size.

The results from the above two experiment clearly shows the differential sensitive of reproductive phase to short episodes of drought and high temperature stress. The traits influenced include seed numbers (percent seed-set), followed by seed-size. At the present most crop models do not have the capability to predict the short episodes of either drought or temperatures stress on growth and yield, particularly with reference to seed-numbers. To have greater confidence in crop simulation models, it is important to consider the impact of short episodes of stress. This poses a challenge to crop modelers to incorporate differential sensitivity of reproductive phase to environmental stress, which could improve the model predictions under current and future climate change conditions.

Impact of Elevated Carbon Dioxide Concentration on Nitrogen Uptake in Rice

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Keywords: rice, nitrogen, transpiration, aquaporins, carbon dioxide

Elevated concentrations of carbon dioxide ($[\text{CO}_2]$) often increase the biomass of C_3 plants while decreasing tissue nitrogen concentrations, and nitrogen supply often limits the response of biomass to elevated $[\text{CO}_2]$. Reasons why nitrogen uptake rates do not increase as much as biomass accumulation rates at elevated $[\text{CO}_2]$ remain unclear.

We measured the uptake of nitrate and ammonium ions and tissue nitrogen contents in rice grown hydroponically in controlled environment chambers at 350 and 700 $\mu\text{mol mol}^{-1}$ $[\text{CO}_2]$. As found previously in free-air carbon dioxide enrichment studies on paddy rice, total nitrogen uptake per plant was not altered by carbon dioxide enrichment, while increased biomass resulted in lower plant nitrogen concentrations at elevated $[\text{CO}_2]$. Measurements of ion uptake rates at three stages of development indicated no effect of elevated $[\text{CO}_2]$ on total nitrogen uptakes rates per plant, but lower rates of uptake per unit of total plant dry mass and per unit of root dry mass. The nitrogen delivered to the root system in the transpiration stream was termed “passive” uptake, and additional uptake was termed “active” uptake. Active uptake was probably related to root growth, as the hydroponic systems were unstirred. The proportion of total nitrogen uptake which was active decreased with plant developmental stage as root growth slowed. Elevated $[\text{CO}_2]$ reduced the passive uptake of nitrogen per unit of root dry mass at each developmental stage, but had no effect on the active uptake of either nitrate or ammonium per unit of root dry mass.

To test the idea that low transpiration rates at elevated $[\text{CO}_2]$ limited nitrogen uptake, short-term experiments were conducted to manipulate transpiration rate and determine the effects on the active and passive uptake of nitrate and ammonium over 24 h periods. In one experiment, plants grown at 350 $\mu\text{mol mol}^{-1}$ $[\text{CO}_2]$ were exposed to $[\text{CO}_2]$ of 200, 350 and 700 $\mu\text{mol mol}^{-1}$. There was a linear relationship between total nitrogen uptake rate and transpiration rate in this experiment, but active uptake also increased significantly with increasing $[\text{CO}_2]$. We speculate that the active uptake increased because root growth rate increased in response to $[\text{CO}_2]$ effects on photosynthesis.

In other experiments, root systems were exposed to HgCl_2 or abscisic acid (ABA) to reduce transpiration rates. The HgCl_2 treatment was used to interfere with aquaporins, which affect the hydraulic conductivity of root membranes, and the abscisic acid treatment was used to cause partial stomatal closure. These experiments were conducted on plants grown at both $[\text{CO}_2]$. Both the HgCl_2 and the ABA treatments reduced transpiration rates and the passive uptake of nitrogen. The HgCl_2 treatment also reduced the total uptake rates of both nitrate and ammonium, but the ABA treatment stimulated the active uptake of both ions. The stimulation of active uptake by

ABA resulted in a net increase in the total nitrogen uptake rate. Similar results were obtained for both $[\text{CO}_2]$ treatments.

We concluded that nitrogen uptake rate in rice at elevated $[\text{CO}_2]$ was reduced partly because of stomatal closure and reduced transpiration rates. We plan to examine root tissue of plants grown at ambient and elevated $[\text{CO}_2]$ using proteomics, to investigate why the increased active uptake of nitrate and ammonium in response to short-term elevation of $[\text{CO}_2]$ did not occur in the long-term $[\text{CO}_2]$ treatments.

Modeling to Evaluate Irrigation Management Strategies to Maximize Cotton Yield and Water Use Efficiency

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Keywords: deficit irrigation, water use efficiency, GOSSYM

Cotton [*Gossypium hirsutum* (L.)] is well adapted to production under semiarid water stress conditions and is grown as the primary crop on much of the Southern Great Plains under both dryland and irrigated regimes. Increasing irrigation costs due to high fuel prices and decreasing well capacity of the declining Ogallala aquifer, compel Southern High Plains agricultural producers to maximize yield while minimizing irrigation input. For example, timely termination of irrigation may promote use of stored soil water. Similarly, smaller but more frequent irrigation applications that do not fill the soil water storage capacity may use rainfall more efficiently by reducing storm runoff. Optimum deficit irrigation of cotton must balance application rate and duration with rainfall and available soil water. Cotton is an indeterminate crop that can produce lint in response to available water; nevertheless the efficiency of water use depends on timeliness of precipitation. Growing season precipitation on the Southern Great Plains varies in frequency and amount, and makes interpretation of short duration field experiments misleading for maximizing long-term yields. Computer crop growth simulation with long-term weather records, however, can efficiently expand the basis for comparing cotton irrigation strategies despite annual climatic variability. Our objective was to compare simulated cotton lint yield and water use efficiency (WUE) for several combinations of irrigation frequency, amount, and duration under two initial soil water conditions and to identify practical irrigation strategies for use with the broadest production scenarios.

With the cotton model GOSSYM (Baker et al., 1983), we simulated growth and lint yields of a stripper cotton cultivar (Staggenborg et al., 1996) grown in rows 0.76 m apart and with 13 plants m⁻² using long-term (1958-2000) weather records from Bushland, TX as input (Baumhardt et al., 2005). To the 50 kg ha⁻¹ N normally mineralized during fallow (Eck and Jones, 1992) in a 1.8 m deep Pullman (fine, mixed, superactive, thermic Torrertic Paleustoll) we added N and P fertilizer (100-50-0) and adjusted plant available soil water contents to either 50 or 100 % for the initial s conditions. We simulated all possible combinations of irrigation frequency (4, 7, 10 – days between applications), application amount (0.0, 2.5, 3.75, and 5.0 mm d⁻¹), and duration (4, 6, 8, and 10 weeks beginning 37 days after emergence). Simulated cotton yield and water use from ~ 3100 tests were compared with the SAS general linear model procedures according to a factorial arrangement of a completely randomized design. The observed climatic variability, including rainfall, of 43 growing seasons (1958-2000) provided the random experimental error source, i.e., replication over time.

Staggenborg et al. (1996) validated GOSSYM for known crop and weather conditions on various soils including the Pullman and concluded that the irrigated crop water use, growth, and yields were consistent with observations. Baumhardt (2002) reported model simulated dryland cotton

yields averaging 464 ± 41 kg ha⁻¹ were not significantly different from the corresponding 433 ± 49 kg ha⁻¹ observed in dryland plots. These results suggest that GOSSYM simulates crop growth and yield response to a broad range of climate conditions and irrigation practices.

Cotton yield, evapotranspiration (ET), and WUE increased with treatments that raised irrigation amount such as increasing irrigation rate and duration. For an initial profile plant available soil water content of 50 %, yield increased from 222 kg ha⁻¹ for dryland up to 701 kg ha⁻¹ for the high 5.0 mm d⁻¹ irrigation rate. But, the 100 % plant available soil water profile diminished irrigation effects on yields that varied from 724 to 892 kg ha⁻¹ for dryland and the 5.0 mm d⁻¹ irrigation rate, respectively. Because rainfall plus soil water from the full profile met much of the cotton water needs, as indicated by dryland yields, irrigation treatment effects on ET and WUE were also diminished. Increasing irrigation rate and duration, however, significantly increased ET for both initial soil water conditions. The WUE increased with irrigation level only for the 50 % initial water content indicating that irrigation replaced needed water not available from the soil. Our test of irrigation frequency to enhance precipitation use with 50 % initial soil water showed that high frequency, 4 d interval, irrigation reduced lint yield to 500 kg ha⁻¹ from 641 kg ha⁻¹ for 10 d irrigation interval. The corresponding cotton ET ranged from 490 to 495 mm for the 4, 7, and 10 d irrigation frequencies; however, calculated soil water evaporation decreased from 297 mm for the 4 d irrigation interval to 268 and 252 mm for 7 and 10 d frequency.

We hypothesized that deficit irrigation (water spreading) of an area would yield less than if the same water resources were focused to increase irrigation on a smaller area plus a complementary dryland area. Based on simulated cotton yields for 50 percent initial soil water conditions and dryland or 2.5, 3.75, and 5.0 mm d⁻¹ irrigations for 8 weeks, we calculated a spatially weighted mean yield for variable irrigation strategies. Irrigation was uniformly applied at 2.5 mm d⁻¹ or variably applied with spatial distributions of 2:1 for 3.75 mm d⁻¹ and dryland and 1:1 for 5.0 mm d⁻¹ and dryland. Simulated cotton lint yields using uniform 2.5 mm d⁻¹ deficit irrigation averaged 453 kg ha⁻¹ compared with 2:1 and 1:1 water consolidating variable irrigation strategies that yielded ~ 475 kg ha⁻¹ for a 5 % increase. Based on these simulations, we conclude that irrigation of cotton grown on soil with 50 % plant available water reservoir using consolidated water resources on a smaller area is a superior strategy to deficit irrigation a large area.

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Development of an Integrated Agricultural Information and Management System

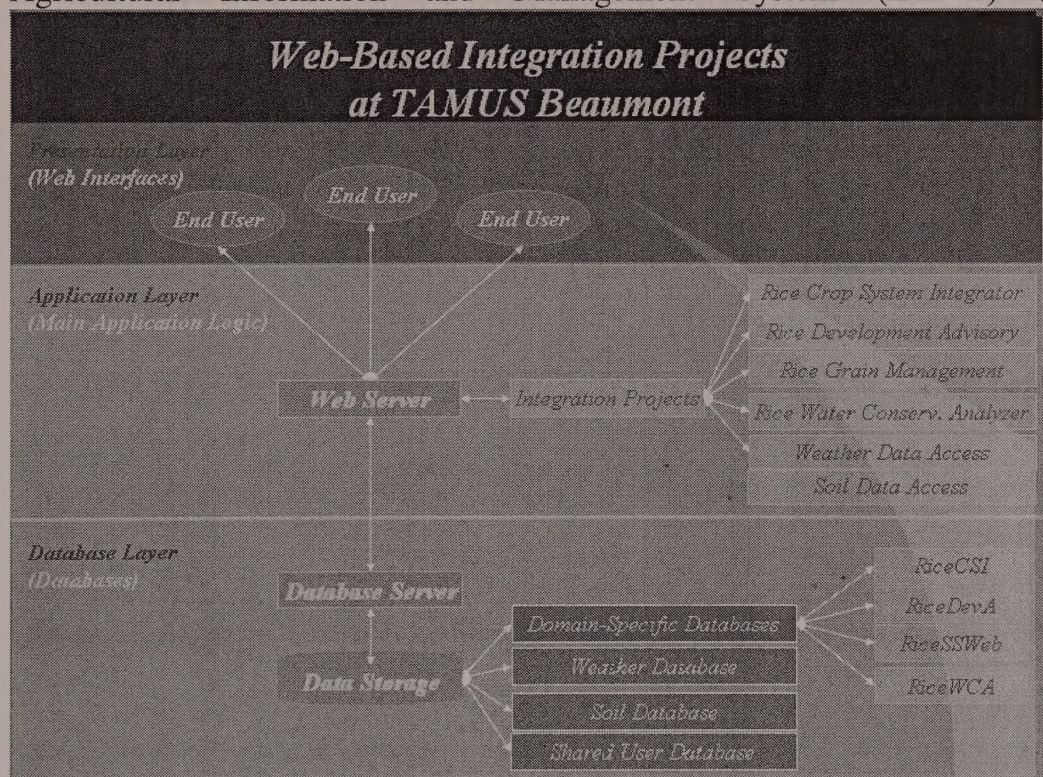
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Keywords: Information, Management, System, Integrated, Weather Database, Soil Database

Over the past century, science has made tremendous advances that have led to major breakthroughs in agricultural production and management. As we enter the 21st Century, agriculture is facing increasing challenges. Continued urban expansion is competing with agriculture for water and other resources. Global competition, combined with trade inequities, continues to shrink U.S. agriculture profit margins. To maintain economic competitiveness, U.S. agriculture must continue to strive for increased efficiency and urban dwellers need to understand how their individual landscape management decisions impact regional use and distribution of natural resources. To insure rapid adoption of improved management practices, information must be delivered in an integrated and easy to use form.

Over the past several years, in cooperation with several state and federal institutions, the Agricultural Research and Extension Center at Beaumont has been developing an Integrated Agricultural Information and Management System (IAIMS) (see Figure below).



The focus of the system is the consolidation and integration of data and knowledge and the effective delivery of research results as decision tools. The system is built around foundation

class climatic and soil databases that are independent of the overlaying crop production systems. The databases provide a common platform for developing diversified applications, which can be shared among researchers, producers, and other interested groups, thus maximizing the use of resources and minimize research redundancy.

A number of applications have been developed that seamlessly access the foundation class databases (Yang et al. 2006, Yang et al. 2004, Wilson et al. 2005, and Wilson et al. 2005). Collectively the applications address water conservation and rice production and management problems in the Upper Gulf Coast. The increasing use of these applications by researchers and producers demonstrates that the IAIMS' framework is a viable approach that can be expanded to address problems involving a wide number of cropping systems across US. An added advantage of the IAIMS' structure is its systems focus, which facilitates cooperation and integration by researchers across a wide range of disciplines.

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Development of an On-Farm Rice Water Conservation Analyzer

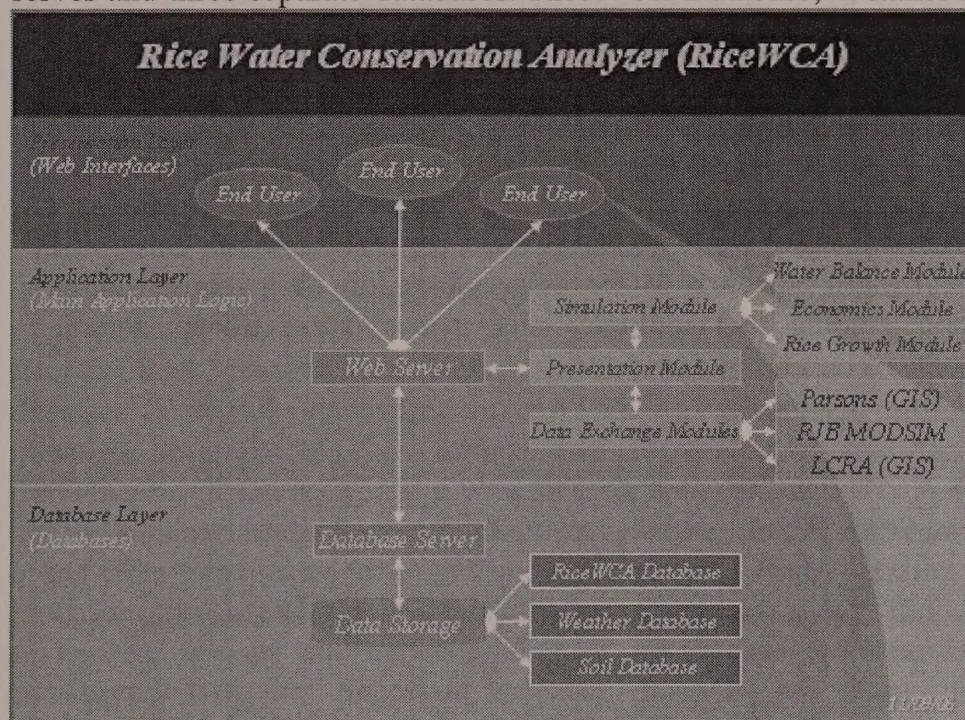
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Keywords: Water balance model, economic model, water conservation

Overview. The objective of this study is to develop a web-based on-farm rice water conservation analyzer (RiceWCA) as a tool to rapidly evaluate the costs and water savings associated with varying degrees of implementation of different rice on-farm conservation measures. On-farm water conservation can be categorized into five conservation practices: 1) precision grading, 2) multiple inlet, 3) conservation tillage, 4) lateral improvement, and 5) tailwater recovery.

System Architecture. The on-farm Rice Water Conservation Analyzer (RiceWCA) is built on the field-level GIS database provided by Parsons (2006). Its overall architecture consists of three distinct layers: presentation, application, and database (see Figure below). The presentation layer is a web-based interface through which users interact with the program (Yang et al. 2006). The application layer contains the main application logic. It consists of a web server and three program modules that interact with the web server: Presentation Module, Simulation Module, and Data Exchange Module. The Simulation Module hosts the water balance module, the economics module, and the rice growth module. The database layer provides data that are needed to run the simulation and stores simulation results for later analysis. It consists of a database server and three separate databases: RiceWCA Database, Weather Database, and Soil Database.



Rice Growth Module and Water Management. The rice growth (i.e. phenology) module used in RiceWCA is a simple rice growth model based on useable heat units. It is assumed that rice

growth and development is solely based on the cumulative heat units above its developmental threshold. The rice growth model is used to time water management events. The main water management events for the main (first) crop include flushing, flush drainage, permanent flooding, and drainage before harvesting. The main water management events for the ratoon (second) crop include permanent flooding and drainage before harvesting.

Water Balance Module. The RiceWCA simulates water balance for both fields and laterals on a daily time step. A water balance model is developed for rice paddy, temporary levee, permanent levee, lateral ditch, lateral bank, and on-farm reservoir (tailwater recovery), respectively. The components of the water balance model include soil saturation deficit, evapotranspiration, percolation, seepage, rainfall, irrigation, and tailwater.

Economics Module. The economics module includes economic models for field and lateral improvement, and for tailwater recovery. It also includes cost sharing, cost amortization and calculation of life time average cost.

Calibration and Validation of the Water Balance Module. The water balance module was calibrated using daily 2001 and 2002 LCRA WAMS irrigation data for *Lakeside* and validated using daily 2000, 2003-2004 LCRA WAMS irrigation data for *Lakeside* and using 2000-2004 datasets for *Gulf Coast*. The calibration analysis explained 99% of the variability in daily cumulative irrigation demand for both 2001 and 2002, respectively. The validation analysis in turn explained 98-99% of the variability in daily cumulative irrigation demand.

Calibration and Validation of the Economics Module. The economics module uses current field conservation practices as a baseline and estimates a partial net benefit with different conservation improvement options. The calibration/verification process includes estimating the best unit price and benefit for each improvement and code verification. Since no data is available for the rigorous statistical process of calibration and validation, the estimated cost/benefit is checked against the cost/benefit data that are available from producers and literature. Based on this comparison, Predicted cost/benefit appears to be reasonable for each conservation improvement, including precision grading and multiple inlet, conservation tillage, lateral improvement, and tailwater recovery.

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Uses and Challenges for Modeling Sustainable Agricultural Systems

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The goal of sustainable farming systems is to maintain production and economic goals while preserving the natural resource base that supports agriculture. Assessment of the sustainability of cropping systems requires a complete analysis of material, economic, and energy flows into and out of the system. Often this is accomplished by analysis of selected key variables such as crop yield, diagnostic nutrient tissue levels, weed/pest infestation levels, net profitability, sediment losses, water quality, greenhouse gas emissions, etc. from comparative systems under study in controlled experimental fields. Long-term experiments can provide important understanding of cumulative system effects on soil quality and unintended ecological/environmental consequences. Simulation models offer an ideal vehicle to preview many scenarios for alternative crops, rotations, planting dates, etc. over a wider range of simulated environmental conditions than could be explored with traditional field testing. In addition, simulations can explore a more complete range of environmental consequences than would be possible in randomized field studies focused on agronomic variables. Models also are essential for scaling results at the farm field scale to the watershed or regional scale.

A fundamental principle of sustainable/organic farming is primary reliance on on-farm natural processes to meet crop growth requirements with the goal of minimizing or eliminating off-farm inputs. This reliance on “natural processes” means that systems include more complex rotations, organic sources of nutrients, and system regulation of weed and pest population dynamics. More complex rotations mean that models need to be available for many crops including cover crops and that the effect of preceding crops/cover crops need to be accounted for in modeling succeeding crops. Inter-planted species are also more common so models need to accommodate simultaneous growth of multiple species. Organic sources of nutrients mean that sub-models of nutrient mineralization from organic matter, availability, and losses from the system are more important to adequately model nutrient uptake by crops than in conventional systems. Weed and pest populations are more likely to be a significant component of sustainable/organic than conventional systems which means that models must be capable of predicting populations of these species and their effect on crops.

An important question for modeling sustainable systems is: Can well characterized processes of material flow and partitioning in crop growth, water and nutrient dynamics in soil, etc. be modeled similarly in conventional and sustainable/organic farming systems or are there fundamental differences in the way these processes function? A second important question is: Do these processes or factors interact according to predictable additive or multiplicative models or are there unexpected synergies and antagonisms. Understanding the integration of component processes is one of the biggest challenges to researchers and practitioners of sustainable agriculture and to our understanding of agroecosystem function. Resolving these system challenges will be important because it will not only impact efforts at modeling sustainable/organic systems but also the fundamental way we think about and approach researching these systems.

Plant Microbe Interactions in Wheat Affected by Different Temperatures

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Keywords: colonization, nutrient uptake, plant-growth-promoting bacteria, temperature

Beneficial effects of rhizosphere bacteria have often been assessed in terms of increased plant growth and for plant growth promoting bacterial strains to be most beneficial, they must firstly colonise the rhizosphere of the host plant (De Weger et al. 1995; Höflich 1995). It is important to understand the factors that lead to the stimulation of their beneficial effects on the host plant. One of the factors that can influence bacterial viability is temperature. Many studies have been conducted to determine the effect of different temperatures on root colonisation of *Pseudomonas* and *Cellulomonas* species for various plants (Ratray et al. 1993; Egamberdiyeva and Hoflich, 2002). However, the effects of temperature on root colonisation of different bacterial species and their effect on plant nutrition have not been fully studied. The aim of our study was to analyse the root colonisation of associate plant-growth-promoting bacteria, specifically *Bacillus subtilis* TSAU12 in the rhizosphere of winter wheat after inoculation at different temperatures.

Soil used in this study was loamy sand and winter wheat (*Triticum aestivum* cv. Naxo) was used for inoculation experiments. Mutants of *B. subtilis* TSAU12 which were marked with antibiotic resistance were obtained by plating the parental strain onto glycerine-peptone-agar supplemented with 120-ppm rifampicin per liter. The inoculation treatments were set-up in a complete randomised design with eight replicates. Inoculated seedlings were then subjected to two treatment regimes, one set was placed in a temperature regulated growth chamber at a light intensity of 20kLux for 16 h at a temperature of 16°C during the day and 8°C at night, and the other in light intensity of 24kLux with temperature of 26°C during the day and 12°C at night. The soil was moistened with water and maintained at 60% of its moisture holding capacity (MHC) throughout the experiment. Plants were harvested 28 days after the emergence of the seeds and analyzed for plant growth, nutrient uptake and shoot root colonisation of bacterial strain. For determination of the soil colonisation with inoculated bacteria, 1g soil was shaken with 10ml sterile water for 30 minutes. For determination of rhizosphere and phyllosphere colonisation, 1 g washed roots, and shoots was macerated and shaken with 10 ml sterile water. The resulting suspensions were evaluated for colony forming units (cfu) according to the dilution-plate method in glycerine-peptone-agar with addition of 120-ppm rifampicin (Höflich, et al., 1995). The data were analysed with a two-way ANOVA and Student-Newman-Keuls test for testing the significant differences ($p < 0.05$) of main effects.

The results showed that inoculated bacteria *B. subtilis* TSAU12 colonised in the rhizosphere of winter wheat during the growth phase up to four weeks after sowing at different temperatures (Fig.1). The bacteria were able to establish in the rhizosphere of winter wheat, which was reflected in the increased development in the root system of annual plants. The strains were not able to survive in the phyllosphere. The root colonisation was higher than soil. The ambient temperature influences the root colonisation activity of introduced strains. The bacterial strains survived after 28 days of treatment much better at 16°C than at 26°C. Ratray et al. (1993) also reported that after inoculation of wheat with *Pseudomonas fluorescens*, the rhizosphere colonization was a better at 8°C than 22°C. Similarly Bowers and Parke (1993) suggest that the density of bacterial population of pea roots was

negatively correlated to an increase in temperature. Höflich et al. (1995) reported that rifampicin-resistant mutant of *Pseudomonas* strain PsIA12 colonised the rhizospheres of different crops in greenhouse and field experiments at moderate temperatures and gave significant increases in yield (Höflich et al. 1995). *B. subtilis* TSAU12 increased root and shoot dry weight of winter wheat at 16°C compared to 26°C. The root growth was stimulated significantly up to 20% (16°C). The strains also increased the P (14%) and K (23%) uptake of root growth (Data not shown). There was no effect on the percentage N uptake. Bacterial strain produce phytohormone auxin which stimulates the root growth of plant. In summary, the final results showed that an increase in temperature was negatively correlated to the density of the *B. subtilis* TSAU12 population of winter wheat. Better colonisation by bacteria was observed at 16 than 26°C. It is postulated that *B. subtilis* TSAU12 is forming a beneficial association with the plants and is producing growth promoting substances as evidence by the increase in plant dry weight and nutrient level uptake.

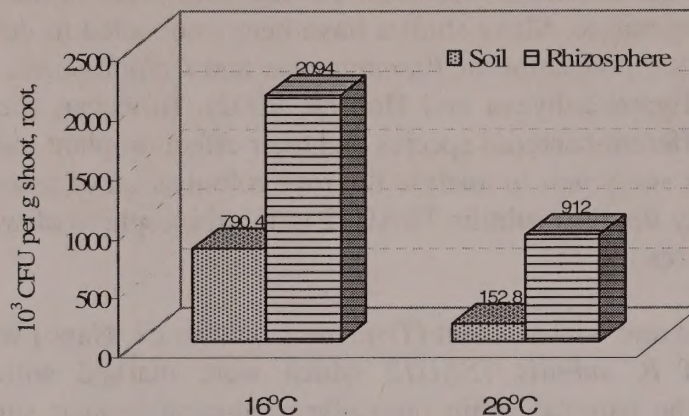


Fig.1. Colonisation of *B. subtilis* TSAU2 bacteria in the soil of the root zone, rhizosphere of winter wheat after inoculation at different temperatures (Pot experiments with loamy sand, values in 10³ cfu per g shoot, root, soil)

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Use of Functional Mapping to Identify QTLs of Root Traits of the Common Bean

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Keywords: logistic growth, root architecture, root development, crop models

Crops with root systems that are efficient in acquiring limiting resources such as water or nutrients are critical for the development of sustainable agriculture. Therefore, many studies have been performed to both model and identify the genetic mechanisms involved in regulating root growth and development. The most commonly used method to identify genes involved in root development is through the use of Quantitative Trait Loci (QTLs). However, most QTL analyses can explain only part of the variation measured in the segregating progeny, indicating that some QTL have gone undetected. One possible explanation is that most quantitative traits are evaluated at one point in time without taking into account their growth and developmental trajectories. Functional mapping is a QTL mapping approach that addresses this and other related problems. Functional mapping models the time-dependent vector for different QTL genotypes using mathematical equations that describe the growth or developmental process (Wu et al., 2006). Here, we measured the length and number of tap, basal, and lateral roots from two landraces (Jampa and Calima) of the common bean for a two-week period from images taken from custom-made rhizotrons. Based on all the root traits, the roots from Calima showed greatest growth compared to the growth of roots from Jamapa. The growth trajectories were fitted to a logistic growth curve $g(t) = a/(1+be^{-kt})$ where a , is the asymptotic or limiting value of $g(t)$ as $t \rightarrow \infty$, k is the relative growth rate, and $g(0) = a/(1+b)$. Results from these analyses will be combined with data from 132 recombinant inbred lines from Jamapa X Calima to identify root traits involved in early root establishment. These growth trajectories can be used to further develop more robust models for root growth.

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The first of these is the fact that the development of the economy is not a linear process. It is a process of continuous change and adaptation to changing circumstances. The second is the fact that the development of the economy is not a uniform process. It is a process of uneven development, with some regions developing faster than others. The third is the fact that the development of the economy is not a purely economic process. It is a process that involves social, political, and cultural factors. The fourth is the fact that the development of the economy is not a purely domestic process. It is a process that involves international trade and investment. The fifth is the fact that the development of the economy is not a purely individual process. It is a process that involves the collective action of many individuals and groups. The sixth is the fact that the development of the economy is not a purely rational process. It is a process that involves emotions, values, and beliefs. The seventh is the fact that the development of the economy is not a purely technical process. It is a process that involves knowledge, skills, and innovation. The eighth is the fact that the development of the economy is not a purely material process. It is a process that involves ideas, culture, and institutions. The ninth is the fact that the development of the economy is not a purely static process. It is a process that involves change and development over time. The tenth is the fact that the development of the economy is not a purely deterministic process. It is a process that involves uncertainty and risk. The eleventh is the fact that the development of the economy is not a purely linear process. It is a process that involves non-linear relationships and feedback loops. The twelfth is the fact that the development of the economy is not a purely uniform process. It is a process that involves uneven development and regional differences. The thirteenth is the fact that the development of the economy is not a purely economic process. It is a process that involves social, political, and cultural factors. The fourteenth is the fact that the development of the economy is not a purely domestic process. It is a process that involves international trade and investment. The fifteenth is the fact that the development of the economy is not a purely individual process. It is a process that involves the collective action of many individuals and groups. The sixteenth is the fact that the development of the economy is not a purely rational process. It is a process that involves emotions, values, and beliefs. The seventeenth is the fact that the development of the economy is not a purely technical process. It is a process that involves knowledge, skills, and innovation. The eighteenth is the fact that the development of the economy is not a purely material process. It is a process that involves ideas, culture, and institutions. The nineteenth is the fact that the development of the economy is not a purely static process. It is a process that involves change and development over time. The twentieth is the fact that the development of the economy is not a purely deterministic process. It is a process that involves uncertainty and risk.

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A Dynamic Model of Water Potential and Movement in Whole Plants Based on Compartment Volumes and Water Contents.

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Keywords: Xylem, Phloem, Water potential, Turgor pressure, Osmotic potential

A whole-plant model of water movement was developed to predict the inter-relationships of water movement in xylem and phloem. The model is based on two concepts. The first concept is compartment volumes and water contents are state variables, which define water potential. The second is that the rate of both short- and long- distance transport are linearly related to an apparent conductance times differences in water potential or turgor pressure. Within one tissue or organ (such as root, stem or leaf), there is rapid short-distance transport of water among cells or compartments due to diffusion. This tends to change the volume or water content of these compartments and equilibrate water potential among compartments. The rate of movement is a linear function of the difference in water potential between compartments times an effective conductivity. Tissue is composed of cytoplasm, xylem, phloem, and apoplast compartments. All transfers of water to and from xylem, phloem, or cytoplasm are through the apoplast, as shown in Figure 1. In combination with solute content, water content or volume also define turgor and osmotic pressure. Water potential has an osmotic component assumed to be linearly related to solute concentration, and a turgor component assumed to be linearly related to change in volume acting on a constant modulus of elasticity. Whereas cytoplasm and phloem have a cell wall which can exert turgor pressure, the apoplast and xylem do not. Water potential in the latter compartments is primarily related to mole fraction per unit volume. Long-distance transport between tissues is due to hydrostatic-pressure driven water flow in xylem and phloem. This flow is assumed to be linearly proportional to the pressure difference times the apparent conductance of the transport path. Pressure differences in xylem are related to water potential. In the phloem, they are related to turgor pressure, see Figure 2. These assumptions can be used to generate a series of linear relations describing water potential and short-distance movement among compartments within one tissue, as well as the linear relations describing long-distance transport in xylem and phloem between tissues. These relations were programmed as finite difference equations using a visual dynamic simulation modeling tool (VENSIM Professional ver 5.6, Ventana Systems). The model was used to examine the effect of diurnal variation in transpiration, and effects of soil-water deficit and solution-root conductivity, on movement of water in xylem and phloem, and on water content of various tissues in an idealized plant.

Figure 1. Schematic diagram of short distance transport among compartments in one tissue.

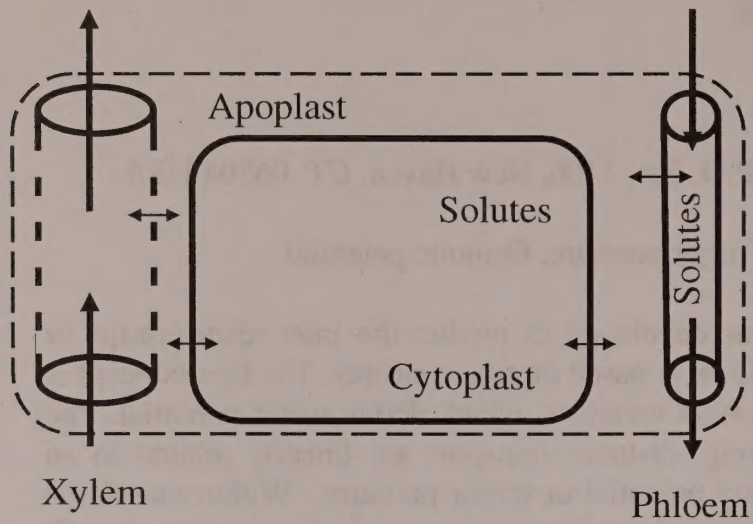
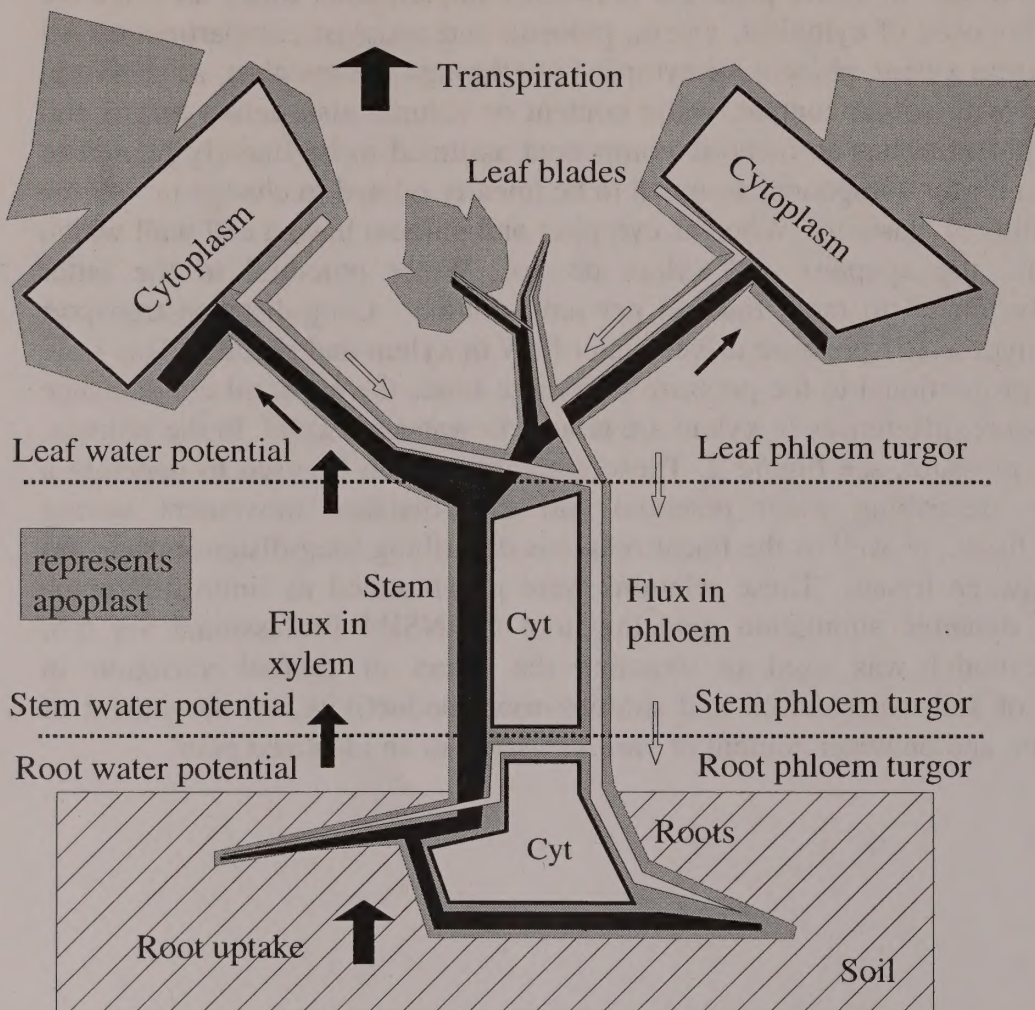


Figure 2. Schematic diagram of long-distance transport of water in a plant.



Global Solar and Meteorological Data for Agricultural Applications

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The National Aeronautics and Space Administration's (NASA's) Earth Science research program has long supported satellite systems and research providing data important to the study of climate variations and variability and climate processes. These data include long-term estimates of meteorological variables and surface solar energy fluxes that have been shown to be accurate enough to provide resource data over regions where surface measurements are sparse or nonexistent. NASA's Earth Science Applications Program has also recognized that the terabytes of scientific data often associated with many of these programs can present formidable challenges to users who have limited resources and/or experience in dealing with large data sets. Moreover, to truly foster the use of these data, NASA has recognized that, in collaboration with data users, scientific data must be tailored by the data providers (i.e. NASA) into user-specific data archives containing the parameters pertinent to a given user community's need. To this end NASA's Prediction of Worldwide Energy Resource (POWER) project was initiated to improve upon existing datasets and to create new datasets from satellite observations and modeling products in support of US renewable energy, buildings, and agricultural industries. In this presentation we describe and give examples of solar and meteorological data products that have been developed or are under development and are focused on the agricultural industry. These products are currently available through the POWER data archive portal at <http://earth-www.larc.nasa.gov/power>.

The POWER archive provides a climatological data base of meteorological variables and surface solar energy fluxes on a global 1° latitude by 1° longitude grid. The daily agricultural data products currently consist of total short wave solar radiation incident on the earth's surface, daily averaged dew point temperature and precipitation, and daily maximum and minimum temperatures. Figure 1 illustrates the sources for the underlying solar and meteorological data (left panel) as well as examples of the global data available in ACCII format from the POWER web site (right panel). The solar data has been derived from satellite observations and offers global coverage over the time periods from July 1, 1983 - June 30, 2005, and July 1, 2006 - present with one month delay; the temperature variables are from the Goddard Earth Observing System Version 4 and 5 re-analyses (GEOS -4, -5) and provides global coverage over the time period from January 1, 1983 - present with one month delay; and the daily averaged precipitation is taken from the Global Precipitation Climate Project (GPCP) and Tropical Rainfall Measurement Mission (TRMM) and provides near global coverage for the time period from January 1, 1997 - present with two month delay.

Besides climatological data sets, NASA is also developing capabilities to produce near-real time data sets consisting of global maximum and minimum daily temperature data from the GEOS Version 5 re-analyses having a 2 to 3 day lag, and global solar energy fluxes from the NASA FLASHFlux (Fast Longwave and SHortwave radiative Fluxes) project having a 4 - 7 day lag. In this presentation we will also show examples of the near real time data products.

POWER Data Sources

ISCCP & CERES/MODIS

Radiance, Cloud, and
Surface Parameters

Aerosols

Satellite and model

Trace Gases

Ozone (TOMS/TOVS)

NASA GMAO GEOS

Temp, Humidity, Wind Profile
and Surface Parameters

NASA/TRMM & NOAA/GPCP

Satellite and Gauge Precipitation

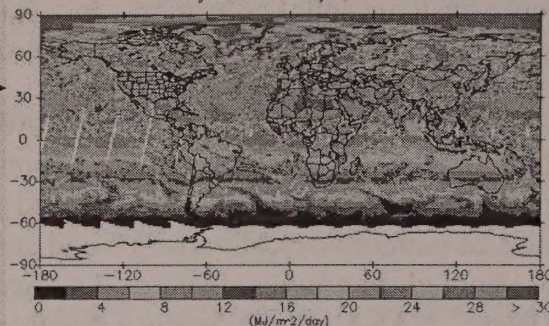
NASA/ GEWEX SRB & FLASH- Flux

Solar
Radiation,
Cloud, and
Surface
Parameters

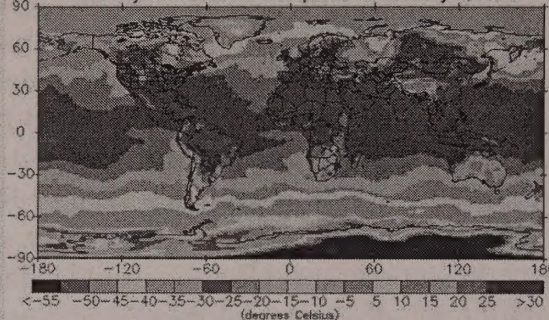
CERES = Clouds and Earth's Radiant Energy System
FLASHFlux = Fast Longwave And Shortwave Radiative
Fluxes from CERES/MODIS
GMAO = Global Modeling and Assimilation Office
GEOS = Goddard Earth Observing System
GEWEX = Global Energy and Water Cycle Experiment
GPCP = Global Precipitation Climate Project
ISCCP = International Satellite Cloud Climatology Project
SRB = Surface Radiation Budget Project
TOMS = Total Ozone Measurement System
TOVS = TIROS Observational Sounder
TRMM = Tropical Rainfall Measuring Mission

POWER Agro-Climatology Rain, Temp, and Solar Radiation On $1^{\circ} \times 1^{\circ}$ Global Grid

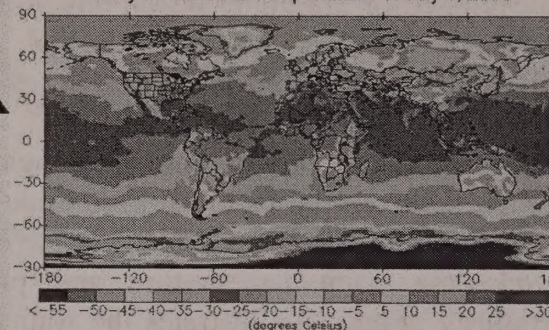
Surface Solar Radiation
Daily Total For July 4, 2006



Daily Maximum Air Temperature For July 4, 2006



Daily Minimum Air Temperature For July 4, 2006



Daily Averaged Precipitation For July 4, 2006

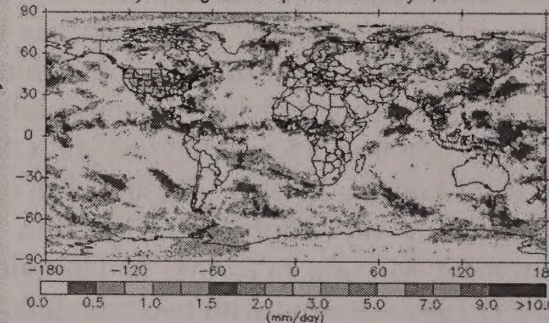


Figure 1. The left hand panel shows the underlying data sources for the agro-climatology data in the POWER data archive (right hand panel).

Impact of Water Availability on the Co-Existence of Grasses and Legumes in Simulated Mixed Swards

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With the raise in atmospheric CO₂-concentrations, global climate scenarios predict for Central Europe an increase in temperature and more frequent summer droughts during the coming decades. The associated negative trend in soil water availability can have major consequences for the fluxes and stocks of carbon (C) and nitrogen (N) in agricultural grasslands, possibly counteracting efforts to mitigate anthropogenic CO₂ emissions through soil C sequestration. Shorter return times of summer droughts may increase the risk of crop failure.

In semi-natural, extensively and intensively managed grasslands, grasses often coexist with legumes such as clover under suitable conditions (see Schwinning et al. 1996a). Coexistence of grasses and clover in mixtures is strongly controlled by their competition for soil mineral nitrogen and light: Under conditions of low availability of mineral N but adequate illumination the relative growth rate of clover is higher than that of grasses because in clover mineral N uptake is supplemented with symbiotically fixed N from N₂. Symbiotically fixed N is transferred to the companion grasses thus maintaining high productivity of the whole sward during periods of N-limitation (Boller and Nösberger, 1987). At high levels of available soil mineral N, on the other hand, the relative growth rate of grasses is higher than that of clover because more light is intercepted by the former.

In the long run, these interactions lead to intrinsic and oscillatory variations in the fractions of grasses and clover. This was demonstrated in a modelling study by Schwinning et al. (1996a) when assuming a constant environment. In reality, these oscillations are also influenced by the variability in climate. More frequent periods of water stress are expected to alter fluxes and stocks of C and N and thus the entire grassland dynamics.

To test these impacts, we adapted the models of Schwinning et al. (1996a) and Thornley et al. (1995). A mixture of ryegrass (*Lolium perenne* L.) and clover (*Trifolium repens* L.) was simulated using, for grass, a simplified version of the Pasture Simulation Model (PASIM, Riedo et al., 1998) and, for clover, a more realistic description of growth. Biomass of grasses and clover were divided into a shoot and root fraction with specific response functions for temperature, soil water and CO₂. Clover growth was parameterized as less drought-resistant than growth of ryegrass.

We calibrated the model with 7-years of data from the Swiss Free Air CO₂ enrichment experiment (FACE) (see Hebeisen et al. 1997). The data refer to biomass and leaf area index for cut monoculture and grass/clover mixtures grown at 370 and 600 ppm CO₂. In addition, we successfully tested the model against observed data from other experimental sites.

We then ran the model for the FACE site to equilibrium, without fertilization and defoliation. Two situations were simulated: 1) a baseline constrained by the observed 1981-2005 climatology and 2) a drought scenario where every second year was replaced by data from the year 2003.

Ambient CO₂ was prescribed for both situations. In the summer of 2003, Europe was struck by an unprecedented heat wave and associated drought (Schär et al., 2004). Favourable growth conditions persisted until June but observed growth was severely impaired later during summer.

In the baseline, the model produced variations in the clover fraction of between 10 and 50%. The period of the oscillations was of 30-40 years resulting from the combined effect of competition, climate and soil moisture on the dynamics of the C- and N-fluxes and stocks. Under favourable growth conditions with adequate water supply, low mineral N and reduced growth of the grasses, between 50 and 350 kg N ha⁻¹ y⁻¹ was fixed by clover and 50 to 250 kg ha⁻¹ y⁻¹ taken up by the grasses.

In the drought scenario, limited soil water availability (close to the permanent wilting point every second summer) impaired the growth of clover relatively more than the growth of grasses. Consequently, the legume fraction varied between 10 and 35% and the average period of the oscillations was reduced to ca. 25 years. With respect to N-dynamics, mineral N stock was replenished more frequently due to the reduction in annual mean rates and N-uptake. This compensated for a reduction in mineralization. Clover growth was limited as a consequence of the assumed more vigorous response to water stress. As a result less N was symbiotically fixed (50-170 kg N ha⁻¹ y⁻¹) and less N was transferred to the companion grass species.

The simulations suggest that, besides the intrinsic oscillatory mechanisms, external factors such as the variability in climate and soil moisture significantly control the relative fractions of grass and clover in mixed swards. The external factors control the intensity of C- and N-fluxes in the plant-soil system and thus the dynamics of the mineral and organic stocks. On the other hand, the co-existence of grasses and clover also depends on the management. This was not examined in our study, but will be addressed in the future.

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An Explicit Model of Canopy Structure to Compare Absorbed Light Distributions in Maize

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Keywords: Maize, light interception, explicit 3D canopy structure

In a recent field trial, yield of Pioneer Maize hybrid 3394 (a 1990's cultivar) was higher than that of hybrid 3306 (a 1960's cultivar) when planted at similar densities. Analysis of the morphology of the two hybrids suggested that upper leaves of 3394 had a more upright posture compared with 3306, but that 3394 also had a smaller total leaf area. Depending on the solar position, more upright leaves should let light penetrate to further canopy depths and cause less shading of neighbor plants. Additionally, more upright leaves should reduce the incident angle of radiation, lowering the absorbed light intensity.

Our research is intended to utilize fine scale measurements of 3D leaf position as an input to a light interception model. We then hope to use the light interception model to determine if important differences exist between the two hybrids in the distribution of absorbed light, when evaluated across the critical times of the growing season. For example, while questions exist to the extent of leaf photosynthesis saturation for C4 maize at higher light intensities, potentially because of its canopy structure, the bulk of the light absorbed by 3394 may be of lower intensity and therefore may be used more efficiently in photosynthesis. We believe an explicit structural model is necessary to adequately evaluate these questions.

A preliminary light interception model has been developed that accounts for both direct and diffuse components of irradiance. The modeled canopy consists of an array of leaf sections from 100 plants, and the 3D position of each 5cm length of leaf is stored. Direct light for each time step is estimated using a projection (or z-buffer) algorithm (Chelle and Andrieu, 1999) wherein the entire canopy is rotated around normal of the current solar azimuth angle an amount equal to the current solar zenith angle. The resulting rotated canopy is then flattened to a 2D grid and the highest canopy element in each grid is assigned to be sunlit. The received light value for each leaf section is then based on the above canopy direct light and the incident angle. All other canopy elements are assigned to be shaded and so receive no direct light. To determine the diffuse light, first for each height increment in the canopy, the percent of canopy cover above that height is determined. A corresponding percent of canopy cover value is then assigned to each leaf section, and all leaf sections in the same height class are given the same value. At each time step, the diffuse light received for a leaf section is estimated based on the above canopy diffuse light value, the percent canopy cover the leaf section experiences, and its orientation.

To date, the morphology data has been collected on from a few individuals of each hybrid and so our canopies are comprised of randomly assigned individuals, and not from plants that were grown together. Additionally, the light interception model has yet to be calibrated against measured light values. Nevertheless, preliminary output from the model suggests important differences in the absorbed light distribution between the two canopies may exist.

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A Crop Simulation Model for Potato Cropping Systems

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Keywords: Biomass partitioning, CropSyst, CSPotato, Nitrogen fate and transport, Radiation use efficiency, Transpiration use efficiency.

Total world production of potato is about 359 million metric tons (2005). China and Russia are the leading countries, with total production of the two countries contributing to 41% of the total world production. The United States ranks fifth in the world with about 5.3% of the total world potato production. The farm gate value of the U.S. potato production is about \$3.0 billion (2005). The Pacific Northwest (PNW; Washington, Idaho, and Oregon) of the U.S. supports a wide range of agriculture production systems with an annual farm gate value of about \$13 billion. The farm gate value of potato production (54% of the U.S. total production) in the PNW is about \$1.5 billion. The Columbia Basin region in southeastern Washington is an important potato production area. The climatic soil conditions in this region are well suited for production of high yields (in excess of 80 Mg ha⁻¹) of high processed quality potatoes. Potato production occurs under irrigation systems, predominantly center pivot and most of it on coarse, low organic matter, sandy soils subject to nitrogen (N) leaching if water and N are applied in excess. Groundwater nitrate (NO₃-N) levels in the region have increased, thus the need to develop improved N and irrigation management practices as well as the need to assess their impacts on the environment.

Simpotato is a potato growth simulation model developed by Hodges (1992) and Hodges et al., (1992) based on the standards of the IBSNAT (International Benchmark Sites Network for Agrotechnology Transfer) project. This model used radiation use efficiency (RUE) for prediction of yield potentials under different production conditions. Our team of researchers have contributed to upgrading the Simpotato model (the upgraded model is called "CSPotato") and integration of this model with CropSyst model (Stockle et al., 1994; Stockle et al., 2003). In the CropSystVB-CSPotato model, potential biomass accumulation was simulated using radiation-use efficiency and transpiration-use efficiency approaches and the lower of the two values was adapted. This integrated model has been valuable for simulations under multi-crop situations in potato rotation cropping systems. In the integrated model, CropSystVB provides the framework for weather, location, soil and crop inputs, and for daily and annual soil and crop outputs. CropSystVB includes a mechanistic approach of the soil-water-plant-atmosphere system. It simulates crop growth and development and soil water and N balances for a crop rotation of several years. When the crop in the rotation is potato, the phenology and growth of potato, as well as the plant N and carbon (C) balances, are simulated by the CSPotato model. The application of the integrated CropSystVB-CSPotato model for prediction of plant growth

and tuber production of a major potato cultivar was evaluated under different nitrogen and irrigation management practices in the Columbia Basin production region in the Pacific Northwest.

The experiment was conducted in a Quincy fine sand (sand content >65%) Benton County, WA. Potato cultivar 'Ranger Russet' (45,600 plants/ha) was used in this study. This cultivar is grown in about 30% of the Washington state potato acreage (about 69,000 ha). The experiment included a factorial combination of: (i) two irrigation regimes—irrigation to replenish full ET or 70% of ET; (ii) three rates of pre-plant nitrogen soil application—either 56, 112, or 168 kg ha⁻¹; and (iii) three rates of in-season nitrogen delivered as fertigation by center pivot irrigation system—either 112, 224, or 336 kg ha⁻¹. Hence the range of total N application for the season was 168 to 504 kg ha⁻¹.

During the growing season the plants were sampled from selected treatments at two week interval, cleaned, and dry matter partitioned into leaves, stems, and tubers were measured. The leaf area index was also measured. The measured values were compared with those simulated by the simulation model to evaluate the accuracy of prediction. Overall, the model prediction compared favorably with the measured values. Therefore, the upgraded and integrated CropSystVB-CSPotato model is a valuable tool to predict the crop growth and tuber production under different growing conditions.

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Effects of Nitrogen Deficiency on Plant Growth and Photosynthesis, and Selection of Reflectance Properties for Physiology in Switchgrass

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Switchgrass is a potential crop that can be considered for bio-fuel use because of its greater photosynthetic efficiency and higher yield capacity. Nitrogen nutrition is an important factor in plant growth and physiology. Developing functional algorithms for growth and developmental parameters such as leaf development, leaf expansion and stem extension rates and photosynthesis are essential for modeling canopy development in the field conditions where N varies greatly over the season. In addition, recent advances in remote sensing coupled with lower cost of acquiring images, have allowed the collection of essential information on growth and physiology parameters temporally and spatially to monitor plant stress. Therefore estimation of switchgrass nitrogen content during the early stages of growth helps crop managers to correct the deficiency, thereby limiting reduction of final yield. An out-door pot culture experiment was carried out to determine the effects of nitrogen deficiency on switchgrass growth, physiology and leaf hyperspectral reflectance properties. Switchgrass cv. Alamo was seeded in 12-L pots filled with fine sand and irrigated with half-strength Hoagland's nutrient solution from emergence to 45 days after sowing (DAS). Thereafter, the following treatments were initiated: (1) control (100% N) continued receiving the half-strength nutrient solution; (2) reduced N to 20% of the control (20% N); and (3) withheld N from the solution (0% N). Photosynthetic rate, photosynthetic pigments, leaf N concentrations and hyperspectral reflectance on the uppermost, fully expanded leaves were determined at 3 to 4-day interval from 45 to 90 DAS. Based on stem lengths, leaf numbers and leaf length measurements growth and developmental rates were calculated. At 90 DAS, dry weights of various plant components were measured. Switchgrass leaf N concentrations declined during the treatment, but the decline was much greater and steeper in the 20 and 0% N treatments due to increased growth (Fig. 1). Maximum photosynthetic, stem, and leaf growth rates were achieved at 4.5 g N kg^{-1} or 2.8 g N m^{-2} leaf area (Fig. 2). All growth and developmental rates declined with leaf N. Photosynthetic rate is more sensitive to leaf N followed by leaf and stem growth rates and leaf addition rates. Under nitrogen deficiency, leaf dry weight had the greatest decrease among plant dry weight components. Nitrogen deficiency decreased the absolute amounts of all plant component dry weights along with the partitioning coefficient. Deficiency of leaf N increased leaf reflectance at 550 and 750 nm wavelengths. Leaf chlorophyll, carotenoids and leaf N content were correlated with simple as well as first derivatives of reflectance and reflectance ratios (Fig. 3). First derivative of reflectance enhanced the predictive capability of leaf N based on weight basis (g/kg) to 93% at 775 nm wavelength. For leaf N estimation on area basis (g/m^2), coefficient of determination was increased to 94% by ratios of first derivatives of reflectance at 765 nm and 615 nm wavelengths. For chlorophyll content, coefficient of determination increased to 87% with first derivatives of reflectance at 765 nm. The N-specific wavebands and the functional relationships developed between leaf N and various growth and developmental processes would be useful in providing functional algorithms for modeling. In addition, the reflectance parameters identified in this study will be useful for non-destructive estimation of leaf N content and thus N management in switchgrass.

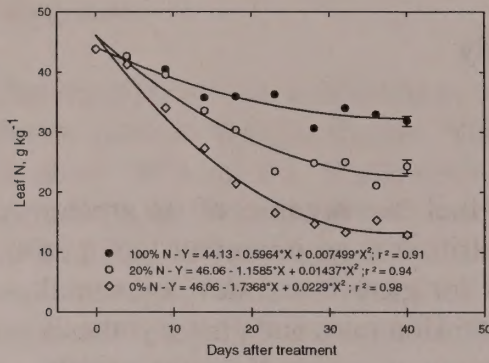


Fig.1. Temporal trends in leaf nitrogen as affected N treatments and plant growth.

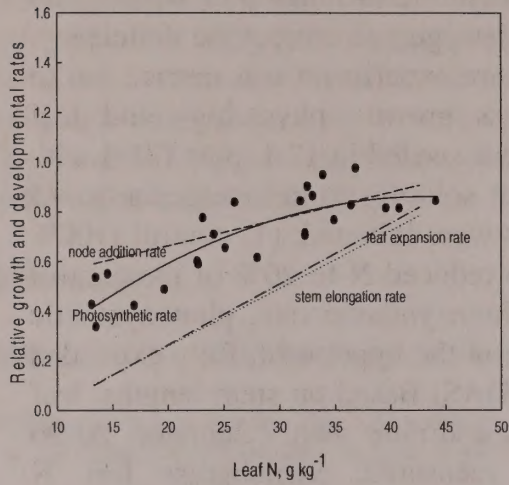


Fig.2. Influence of leaf on growth and developmental parameters of switchgrass expressed as fraction of maximum rates observed at optimum N concentration.

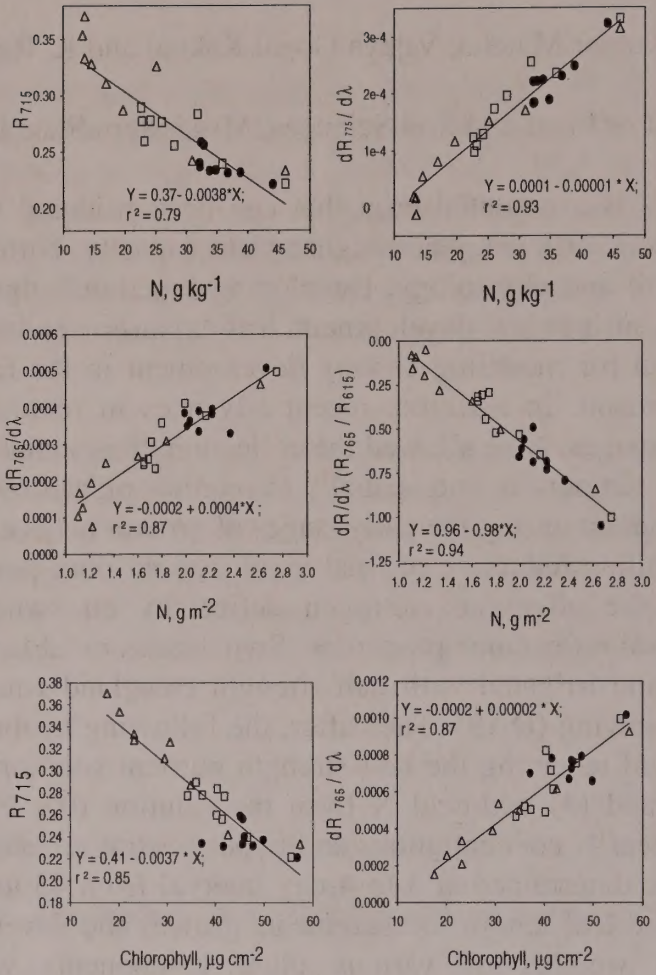


Fig.3. Linear regression of switchgrass leaf N, based weight and area based expressions and chlorophyll with a given reflectance, ratios of reflectance and first derivatives of reflectance.

Coupling of a Crop Growth Model with FUSSIM2 to Simulate Maize Crop Responses to P-Uptake.

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Key words: Crop growth, dynamic model, maize, nutrient uptake, phosphorus

Introduction

Modeling nutrient uptake by crops implies considering and integrating processes controlling the soil nutrient supply, the uptake by the root system and relationships between crop growth response and the amount of nutrient absorbed. We developed a **mechanistic model** that integrates both dynamics of maize growth and phosphorus uptake (Mollier *et al.*, 2007). A crop growth model including the crop P-response was coupled to FUSSIM2 model (Heinen, 2001). FUSSIM2 is a 2D simulation model which describes water movement, solute transport and root uptake of water and nutrients in partially saturated porous media (*see P de Willigen et al. communication in this conference*). The objective assigned to the model was to predict P-uptake and maize crop response under sufficient P-availability or a moderate P-deficiency. Data from a field P-experiment were used to evaluate the model predictions.

Model description

The model is made of three modules closely connected. The first one deals with **crop growth** and **crop P-demand**. Crop growth is described by plant phenology and biomass accumulation depending on climatic conditions. Crop P-requirement is derived from potential leaf area expansion rate using a closed relationship between leaf area index and total P-uptake obtained from a long-term field fertilization experiment with different soil P-availability during the vegetative growth period (Plénet *et al.*, 2000). The second module describes **P-supply from the soil** considering the soil solution concentration and the soil buffer capacity. The third module deals with the crop P-uptake. The P-uptake model is a 2D model and is derived from FUSSIM2. The soil domain is subdivided into square control volumes (CV). Each of them is characterized by soil properties and root length density. The microscopic model for nutrient uptake developed by de Willigen and van Noordwijk (1987) is used for each CV. Phosphorus transport within the solution of the soil cylinder around the root is driven by **mass flow and diffusion**. A complete regulation of P-uptake by the roots according the crop P-demand and soil P-supply was assumed. Required P-uptake cannot occur when the diffusion and mass flow processes in the soil cannot replenish enough P to the root. We assumed that the maximum uptake rate equals the maximum possible rate of P-transport to the root, i.e. the roots behave as a zero sink. The actual P-uptake rate was the minimum of the required P-uptake rate and the maximum P-uptake rate previously calculated.

The crop growth is calculated from the actual carbohydrate assimilation and the actual P-uptake as follow. If the crop P-demand is satisfied, the effective growth is only limited by carbohydrates availability. If the actual P-uptake is less than required, the leaf area expansion rate is reduced according to the P-shortage. Because of reduced leaf area expansion rate, fewer carbohydrates are allocated to the shoot so that more carbohydrates are directed to the root system.

The new root length is distributed in the soil based on the diffusion-type root model (de Willigen et al., 2002).

Results and discussion

Model calculations for P-uptake and crop growth were compared to field measurements on a long term P-fertilization trial. Three P-fertilization regimes (no P fertilization P0, 42.8 kg P ha⁻¹ yr⁻¹ P1.5 and 94.3 kg P ha⁻¹ yr⁻¹ P3) have led to a range of P-supply. Our model correctly simulated both the crop development and growth for all P-treatments. P-uptake was correctly predicted for the two non-limiting P-treatments (Fig 1a). For P0 the model predicted correctly a severe reduction in P-uptake during the early period of growth but predicted P-uptake was underestimated at the last sampling date. For P3 and P1.5, the simulated LAI was closed to observations and model efficiency was high (Fig 1.b). For P0 the model predicted a severe reduction in LAI associated to the P-uptake decreased. The root growth response to P was also correctly predicted (Fig 1.c). For P0 the reduction in root growth was less severe than for shoot growth reduction. Consequently the model predicted a higher root/shoot ratio for P0 in response to P-shortage. The field measurements indicated that R/S ratio increased for P0 but to a lesser extend than predicted.

Conclusions

The proposed model correctly simulated the crop development and growth under non-limiting P-conditions. The crop growth processes, which were affected in the low P-treatment, were also correctly simulated. Nevertheless, for the low P-treatment, the P-uptake was correctly predicted until 259 °Cd (43 DAE) and underestimated 336 °Cd (50 DAE). Despite these discrepancies, the model appears to be an appropriate basis for developing P-fertilization strategies based on soil properties, crop requirements for P and other environmental conditions.

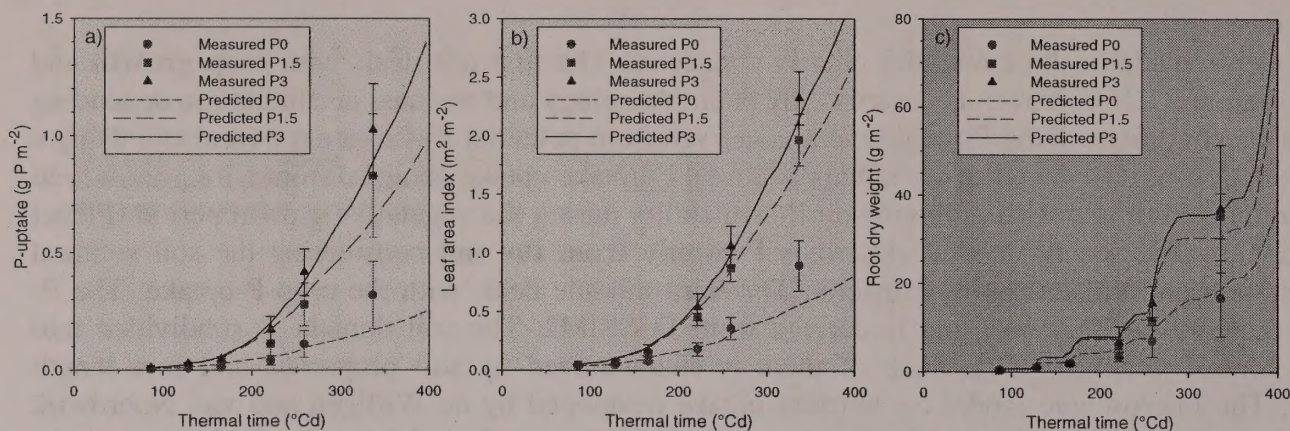


Fig. 1. Comparison of measured (symbols) and simulated (lines) time courses of (a) cumulated P-uptake (g P m⁻²), (b) leaf area index (m² m⁻²) and (c) root biomass accumulation (g m⁻²).

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Modification and calibration of a simple semi-mechanistic model of phosphorous uptake of wheat growing in an Andisol soil

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Keywords: Phosphorus uptake, volcanic soils, wheat crop.

Introduction

Phosphorus (P) deficiency limits crop yield in parts of the world, particularly in countries where fertilizers are significant among production costs. Also, in countries where P levels in soil are higher than required for crop production, it becomes a possible cause of environmental pollution. Some uncertainties in the way that fertilization practices should be adjusted to different crops and soil conditions also remain. Yield crop response to fertilizer application is proportional to crop nutrient (P) uptake whose amount does not only depend on available P but also in crop capacity to absorb available P (i.e. crop uptake efficiency). The remaining question on this concept is one of the main causes of uncertainty in regards to fertilizer management. Models are considered a combination of hypotheses and this work aims to modify and calibrate hypotheses related to development and growth of a wheat crop and its phosphorus nutrition. Some of the hypotheses used in this work are well established in the subject literature for decades while others are more recent. Among the last ones are (a) P crop uptake depends on the internal demand of crop and not only on the available P level and (b) soil concentration of available P is heterogeneous. The objective of this work is to modify and calibrate a version of a simple semi-mechanistic model of P uptake by a wheat crop in the agroecosystem with volcanic soil in Valdivia (Chile) and to identify areas where model performance were not adequate and to propose future modifications.

Materials and Methods

The model was constructed using Microsoft Office Excel version 10 and 11 and simulates -from sowing to physiological maturity- daily growth and development of a wheat crop, the above ground and root biomass accumulation and also the P uptake. For calibration, a field experiment sowed in august 2001 in an Andisol belonging to experimental Station of the Facultad de Ciencias Agrarias of the Universidad Austral de Chile, located in Valdivia, was used. The field experiment was designed with four treatments: three rates of P fertilization: 48, 122 and 200 kg P ha⁻¹ to give sub optimum, optimum and supra optimum P nutrition. The fourth treatment was without application of fertilizer and considered as the deficient level of P in this soil (8 mg kg⁻¹ Olsen-P). Climatic information needed as input variables were registered in the climatic station of the Universidad Austral de Chile.

The model of P uptake

The soil where the wheat roots can obtain P was divided in four 10 cm layers. The potential rate of P uptake in each layer ($TABRn_i$) was simulated as:

$$TABRn_i = GIn_i * RDnF_i * VG * 2 * \pi * RO * IM$$

where GIn_i is the number of granules intercepted by the roots from each soil layer, $RDnF_i$ is the root density (cm cm⁻³) in the soil volume affected by the granule of fertilizer, VG is the volume

of soil influenced by the grain of fertilizer dissolution (cm^3), RO is the mean radius of wheat roots (cm) and IM is the maximum influx of P ($\text{g P cm}^{-2} \text{ day}^{-1}$). Restrictions to the potential rate of P uptake (PGR_i) are given by two concentration borders in which the P concentration in wheat plant can move: CP_{max} and CP_{min} . Both parameters depend on the development stage of the crop (CRL_i). It is assumed that P uptake depends on P demand (DP) from the crop to satisfy a growth rate and that in optimal condition of P nutrition the accumulated P uptake (ABR_i) should be higher than minimum P demand (DP_{Min_i}), which is P demand considering CP_{min} . In this way if accumulated P uptake is bigger than P demand there is no restriction to the potential rate of growth. Otherwise, the potential rate of growth is restricted linearly as:

$$GR_i = PGR_i * \left(\frac{TABR_i}{TABR_i + DP_{Min_i} - ABR_i} \right)$$

where GR_i is the actual growth rate with a P deficiency.

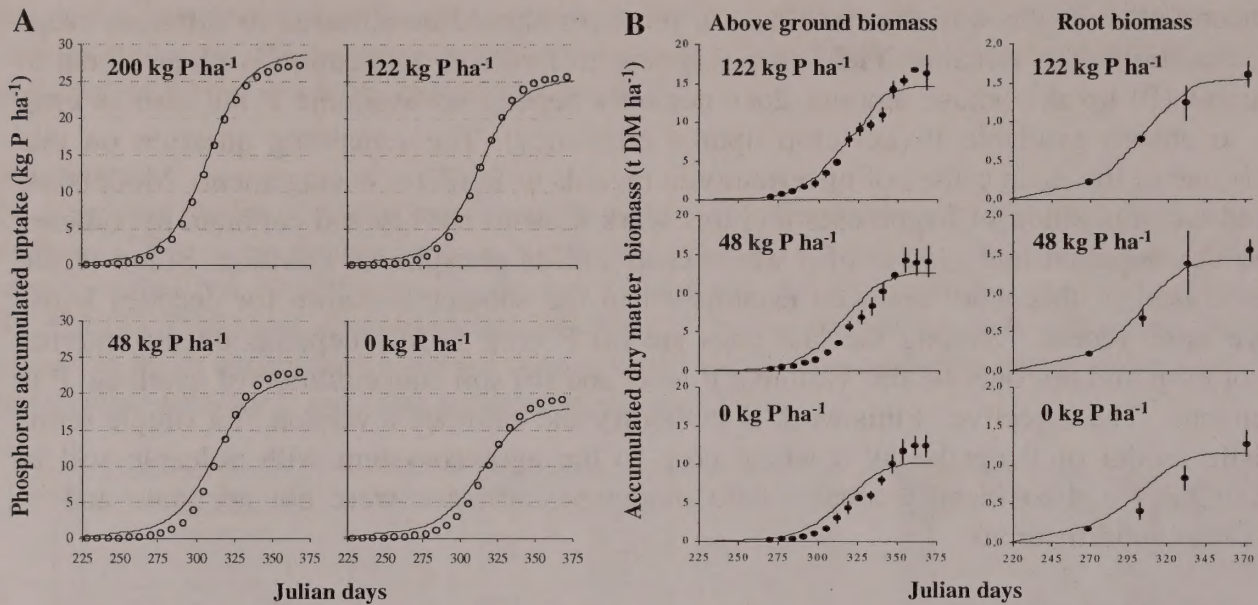


Figure. A. Accumulated P uptake. B. Wheat accumulated dry matter yield. Solid lines are simulated values. Symbols are measured values.

Conclusions

This model was modified and calibrated satisfactorily on the basis of available measurements. However, its inability to simulate adequately intermediate variables in its performance (i.e. root density) arises certain doubts about its actual robustness. Future model modifications should deal with the way daily rate of P uptake is calculated and also include a mathematical representation of crop internal use of P. In addition, it is necessary to improve the way in which the model simulates growth rate decrease when P is deficient. This leads to study the actual way that a minimum P concentration is generated in plants and the form that growth is restricted when P availability is low.

Acknowledgment: This work was supported by the Chilean government through the Fondecyt 1010163 "Study of the phosphorus efficiency uptake of crop with different root densities".

Nitrogen and Irrigation Management of Sweet Sorghum in Texas

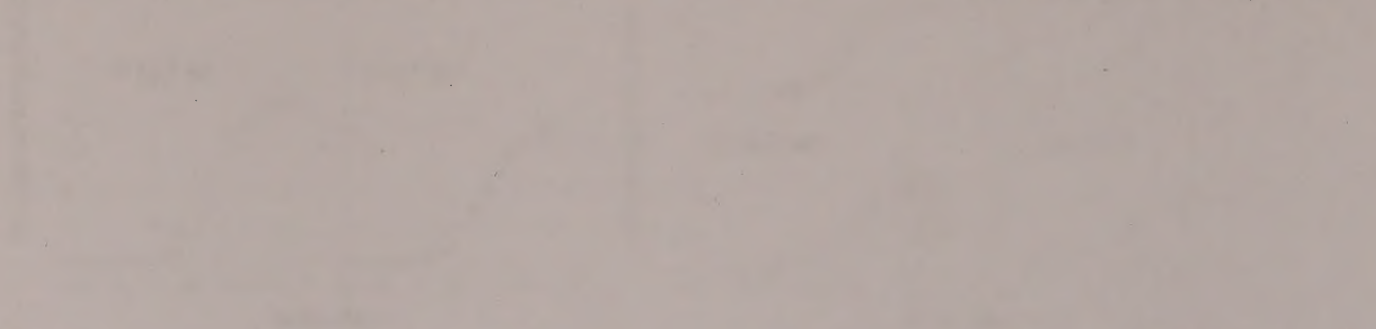
W. Rosenthal, W. Harman, J. Blumenthal, and W. Rooney

Texas Agricultural Experiment Station and Texas A&M University

Keywords: sweet sorghum, EPIC, ethanol, ratoon

Sweet sorghum is a potential crop for producing ethanol throughout the country. In 2006, several varieties were planted at the Brazos bottom near College Station and at Bushland. Two crops of irrigated and dryland sweet sorghum were harvested at College Station and an irrigated crop was harvested at Bushland. Crops were hand harvested and fed through a press to collect the juice. Total estimated potential ethanol production was 400 and 217 gallons/acre for the irrigated and dryland treatments, respectively. Through improved nutrient management practices, it is estimated that production can increase 10%. Production costs are calculated to be similar to grain sorghum, but harvesting and transportation costs are substantially different. To minimize loss of organic matter from the soil, it is suggested to rotate sweet sorghum with cotton or other grain crops every third year. EPIC, a crop simulation model, was used to calculate long-term production at both locations with varying irrigation and nutrient applications. Results will be summarized in the presentation.

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Towards an Equilibrium P-Fertilization of Vegetable Crops: Modeling the Effect of P Placement

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In the Netherlands a surplus of organic manure has improved soil fertility, especially in regions with intensive livestock raising (hogs, poultry). Nowadays P-fertility status of the sandy soils in the southern part of the country is high, as well as nitrogen mineralization rates. Environmental concerns about the quality of ground and surface water have forced the national government (endorsed by the European Union) to regulate the N and P input on land used by farmers. For nitrogen, crop –specific application rates were developed to meet the EU nitrate directive (< 50 mg nitrate/L groundwater). For P a maximum input of $37 \text{ kg ha}^{-1} \text{ yr}^{-1}$ is now allowed but further reductions are to be expected in the near future. An equilibrium fertilisation strategy for P, to be reached in 2015, is foreseen. This implies that P-application rates have to be proportional to maximum P uptake and P off take. Especially farms with intensive vegetable growing are expected to have difficulties in realizing such an equilibrium fertilisation. Because, in general, Dutch recommended P-application rates for these (short growing) crops are higher than for longer growing crops, in spite of higher uptakes and off take for the latter.

In a desk study, a cylindrical simulation model for water uptake, nutrient uptake and crop production (see de Willigen et al. (2007) this conference) was used to explore the rationale behind this negative relationship between recommended P-application rates and P off take. Due to the immobile character of the phosphate ion, root length determines to a great extent the potential P-uptake capacity (de Willigen and van Noordwijk, 1987). However, it is questionable whether inherent crop rooting characteristics can explain the paradox mentioned above. We hypothesized that root length is mainly a crucial factor in the juvenile growth phase. Obviously, the daily P-demand of the crop is low, but so is root length. The consequence might be that P-uptake rate expressed per cm root length in the early stages of growth is high and therefore available P needs to be relatively high to meet the demand. Results obtained with the simulation model for leeks support this.

Such an imbalance between root length and P demand will be extra harmful for crops with a short growing period. The consequence is that for a good yield and quality of the main vegetable crops a relatively high P status of the soil is needed just to support the plants through the short phase when root length is limiting P uptake. On the other side it also means that relatively small amounts of P would suffice to maintain the productivity at a lower soil P status, provided that these amounts are applied in the vicinity of the young plant roots. The effect of placement of P-fertiliser, as compared to broadcast application, was therefore explored with the model for a range of P-fertilities of the soil. Practical implications for nutrient management will be discussed.

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On The Use of Radiation and Water-use Efficiency for Biomass Production Models

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Keywords: modeling, wheat, photosynthesis, canopy transpiration, crop growth

Simple biomass production models are used to assess performance of crops under a wide range of environmental and management conditions, typically as a component of comprehensive crop growth models. Two simple biomass production models are widely used, one based on radiation-use efficiency (e), and the other on water-use efficiency (w)

$$\sum B = e \sum Q^O f_i \quad [\text{Eq. 1}]$$

$$\sum B = \sum wT = K \sum T / D_a \quad [\text{Eq. 2}]$$

Where B is biomass, Q^O is incoming (above canopy) solar radiation, f_i is the fraction of incoming solar radiation intercepted by the canopy, T is transpiration, and K is transpiration to biomass coefficient, which divided by the air vapor pressure deficit (D_a), allows estimating w . The expectation is that normalization by D_a would account for the effects of climate variations on w , while k would be reasonably constant across diverse environment.

The usefulness of these models depends on how conservative e or K are across locations or as solar radiation, temperature, humidity, and wind patterns change throughout the crop growing season. However, the evaluation of the transferability of these parameters is not simple due to the scarcity of experimental values and the lack of methodological consistency of the available experiments. For this reason we developed and tested a canopy transpiration and photosynthesis (CTP) model, and we use it to obtain simulated values of e , w , and K for wheat in eight world locations with diverse weather but the same crop and soil conditions (Kremer, 2006).

Our results showed that e is not conservative but fluctuates significantly. However, e correlates with D_a (Fig. 1), incoming solar radiation, and the diffuse fraction of this radiation, which should allow estimation of e as a function of these weather variables. Unfortunately, these weather variables are cross correlated and their individual effects are hard to separate. In addition, their correlation with e is not as strong as desirable. Assessment based on experimental data has pointed to similar results. Another factor contributing to fluctuation of e is temperature outside the optimum range for photosynthesis, particularly the combination of cool and sunny days. Models of biomass production based on water-use efficiency are affected much less by cool temperatures because photosynthesis and transpiration are both reduced.

Figure 1

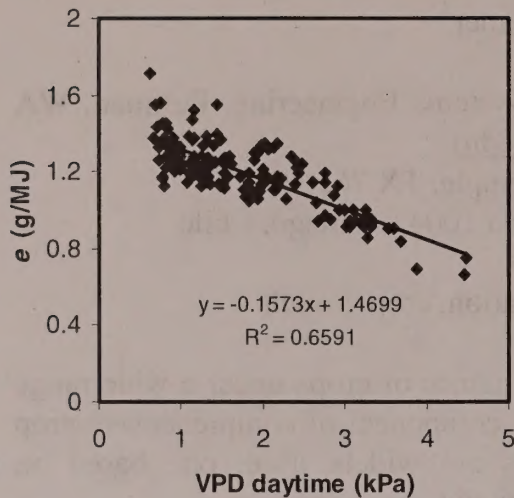
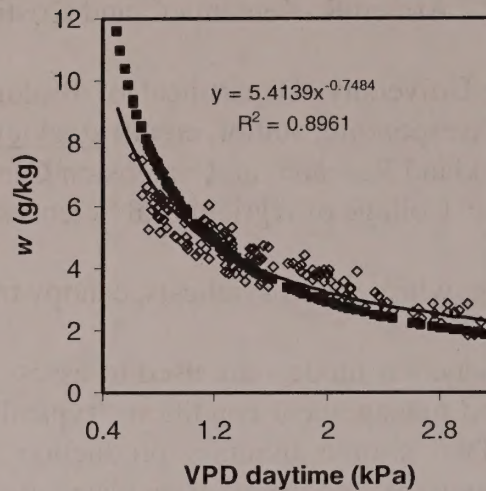


Figure 2



As expected (Eq. 2), w was non-linearly related to D_a (Fig. 2). A constant K value ($K=5.8$ kPa, shown as black squares in Fig. 2) resulted in over or under estimation of w at low and high D_a , respectively. Indeed, K is a function of the internal (sub-stomatal cavity) to atmospheric CO_2 concentration ratio, which is not constant as usually assumed and seems to depend on D_a as discussed by Kemanian et al. (2005). The power function (Fig. 2) describing the change of w in response to changes of D_a can be rearranged if desired to estimate K as follows: $K = 5.4D_a^{(1 - 0.75)}$.

Crops with C_3 photosynthetic pathway are likely to show similar w responses to D_a as shown here for wheat. The main differences are likely to be associated with differences in respiration, particularly growth respiration, and carbon partitioning to roots, shifting the correlation line up or down. The shift can be approximated by calculating the ratio (R) of the maximum e value (as found at low D_a conditions) for the crop of interest to that of wheat, and using R as a multiplier of the power function while keeping the slope unchanged.

Biomass production estimation using water-use efficiency requires accurate estimation of crop transpiration, but this is essentially the case in any application where soil water could be a limiting factor, regardless of the approach used to estimate biomass gain.

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SOFTWARE DEMO: C-FARM: a Simple Model to Evaluate the Carbon Balance of Soil Profiles

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The principles for modeling soil carbon (C_s) dynamics have been established during the last decades and have been compiled in several simulation models. Early models consisted of one C_s pool and one residue pool (e.g. Hénin and Dupuis, 1945) that evolved to multi-compartment pools that represent explicitly the microbial pool and separated residues and several C_s compartments (McGill et al., 1981; Jenkinson, 1990; Parton et al., 1994; Coleman and Jenkinson, 2005). Single-pool models can be effective in predicting C_s if formulated properly, are amenable for management- or policy-oriented applications at watershed or cropping systems scales, and their calibration requirements are much simpler than those of complex models.

Hénin and Dupuis (1945) proposed a simple framework to analyze soil carbon dynamics, where soil carbon decomposition is assumed to follow first order kinetics: $dC_s/dt = hC_i - kC_s$, where C_s is soil carbon (Mg ha^{-1}), t is time (year), C_i is carbon inputs (Mg ha^{-1}), h is a humification factor and k is the apparent soil decomposition rate (year^{-1}). This model proved useful for hypothesis development and testing and for field-level data interpretation (Huggins et al., 1998a,b). With the objective of accounting for soil properties and environmental factors on h , C_i , and k while keeping the simplistic approach of Hénin and Dupuis (1945), we developed C-FARM, a simple soil carbon model designed to compute decomposition rates for soil profile on a layer by layer basis. No calibration is required for using C-FARM. Both k and h are a function of the C_s content of the layer under consideration. The higher C_s the higher k (based on Huggins et al. 1998b), and the lower h (based on Hassink and Whitmore, 1997). The differential equation for each soil layer is as follows:

$$dC_s/dt = h_c[1 - (C_s/C_{sx})^n]C_i - f_e f_i k_x (C_s/C_{sx})^m C_s,$$

where h_c is the organic carbon inputs humification (yr^{-1}), which is a function of soil clay concentration and residue type (aboveground, belowground biomass, or manure), C_{sx} is the saturation carbon concentration for that layer (Mg ha^{-1}), n and m are empirical constants, k_x is the apparent maximum soil carbon respiration rate (yr^{-1}), and f_e and f_i are factors accounting for environmental and tillage effects on soil apparent respiration rate.

In a prototype Visual Basic for Applications version of the C-FARM estimates of aboveground and belowground C_i are obtained from crop growth simulations based on generalized parameters for several major crops to define radiation interception, transpiration, and biomass accumulation. Estimates of h range from 0.10 to 0.20 yr^{-1} for fresh residues (Rasmussen and Collins, 1991; Huggins et al., 1998a) to 0.30 to 0.35 for manure-derived carbon (Kätterer and Andrén, 1997); Buyanovsky and Wagner (1997) suggested $h = 0.4$ for native prairies and pastures sods. Estimates of k for Midwest soils range from 0.8 to 3.5% year^{-1} (Huggins et al., 1998b) with variation associated to soil type, management, and C_i level. Andriulo et al. (1999) reported a positive relationship between

temperature and k for cultivated soils in the plow layer ($k = 0.08 \text{ year}^{-1}$ for average annual temperature of 27°C).

In C-FARM, h_c is a function of soil texture and is different for root and aboveground biomass. The concept of soil carbon saturation (C_{sx}) (Hassink and Whitmore, 1997) was accommodated through h ; it reaches zero when $C_s = C_{sx}$. The rate of h decay is controlled by n , an empirical constant. Local effects of climate and soil type are accounted for through factors affecting the apparent soil decomposition rate k ($k_x = 0.055 \text{ yr}^{-1}$). The factor f_e combines both soil temperature and moisture effects on k and is computed daily as the product of both soil temperature and moisture limiting factors. Soil temperature and water content are simulated daily for each soil layer by running simplified soil water and energy balances. Tillage accelerates soil turnover rates and mixes soil layers along with all the state variables (moisture, organic matter, and residues). Tillage effects on k are accounted for with an empirical factor that varies from 1 to ~ 2.5 , and depends on the tool utilized, number of passes and soil texture. The effect of each tool was developed by modifying the methodology used by the USDA National Resource Conservation Service to compute soil disturbance ("soil disturbance rating"). We are currently testing this model against several long-term data sets. Future developments before software release include erosion and denitrification estimates. These modifications will be incorporated preserving the robust structure, minimum inputs, and no calibration requirements of the current version.

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SOFTWARE DEMO: Raithu 2006 – Cotton Model With Advanced Analysis Approaches

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Keywords: Modeling, Simulation, MAFES, GUICS, FORTRAN, Visual Basic 6.0, OOPS Model, Interface.

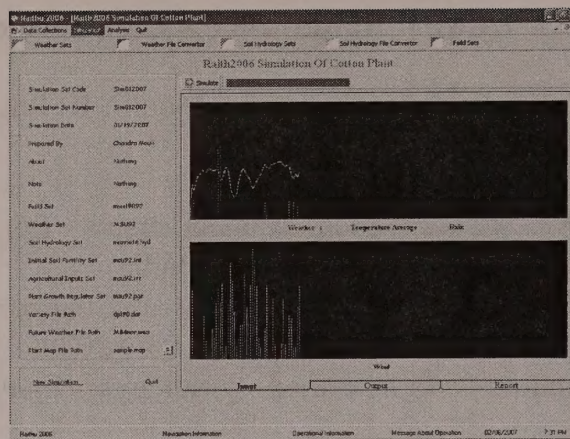
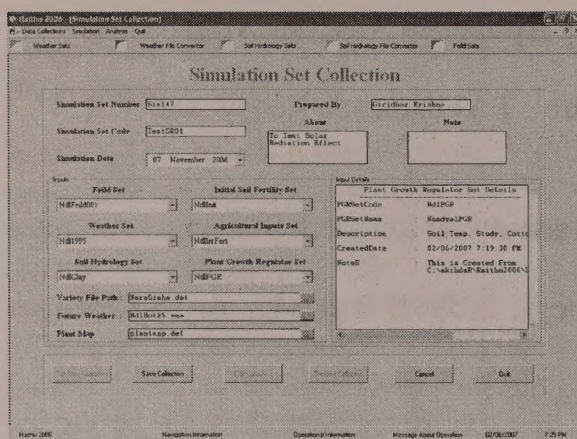
Modeling provides a kind of virtual reality and enables unique simulation and analysis features. Use of crop models helps in advancing our research work, which in turn provides information for understanding the crop growth behaviour.

‘Raithu 2006’ released by Regional Agricultural Research Station, Nandyal, Andhra Pradesh, takes modeling to a new era of advanced approaches. This cotton modeling software provides features for the user to analyze the simulation to arrive at appropriate decisions. It deals with the different environmental conditions, different simulation requirements and evaluates complete picture on cotton crop growth behaviour.

Base Horizon:

Cotton is an important fiber crop grown in Andhra Pradesh, India. In order to advance research on cotton, a cotton-modeling tool is essential with required capabilities, which supports the native cotton growing conditions. For this, RARS, Nandyal developed and released a new cotton modeling tool ‘Raithu 2006’ based on *MAFES* model available with *GUICS*, the cotton simulation model of *USDA, Beltsville*. The new model is developed using advanced designing techniques with object oriented programming structure.

Basically the model should utilize computing power to the maximum possible extent, and support the user with the complete analysis. By this, user can better utilize the model with little efforts. The *MAFES* model has its base code in *FORTAN* language, which is not easy to modify, as *FORTRAN* is not a good language for interface development. Hence, *Raithu 2006*, the extension of *MAFES* model developed in *Visual Basics 6.0*, in which we can incorporate the advanced analysis features easily. This model was developed by completely redesigning the structure of the base code using *OOPS* model and have the GUI based user-friendly interface, where user can perform the simulations with ease.



Application - Overview:

This application, allows the user to manage the data as different data sets like weather, soil hydrology, variety details, irrigation and fertilization. Different forms are provided for easier entry of data with less error. The user can create different simulations by combining varied input data sets. The user can run any simulation with single click and can view the simulation on screen and print outs of the results.

Features – Advantages:

- The Raithu 2006 is a full-fledged GUI based simulator, possessing good user-friendly environment.
- It allows the user to frame the input in the user specified units and view the results as the same.
- The application provides in-line details of simulation while the simulation is running.
- It supports the in time charts by which user can better analyze the simulation. It supports the user with real-time charts, graphs, complete and user specified reports for clear understanding of the simulations and taking decisions more precisely.
- The interface has the ability to run multiple simulations at a time by which we can compare and understand different simulations at a single glance.
- The model is more flexible to user with the available customization options.

Raithu 2006 is an attempt to introduce new techniques to the user in cotton crop growth modeling research. Also it hastens the cotton research in the country.

Remote Sensing to Test Distribution Models of Invasive Species

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Leafy spurge (*Euphorbia esula* L.) is a noxious invasive weed that infests over 1.2 million hectares of land in North America. One of the fundamental needs in leafy spurge management is cost-effective, large-scale, and long-term documentation and monitoring of plant populations. Leafy spurge is a good candidate for detection via remote sensing because the distinctive yellow-green color of its bracts is spectrally unique when compared to co-occurring green vegetation. During 1999, Airborne Visible / Infrared Imaging Spectrometer (AVIRIS) imagery were acquired in northeastern Wyoming and ground vegetation data were collected nearby Devils Tower National Monument in Crook County, Wyoming. Hyperspectral analyses were used to classify leafy spurge presence/absence; overall accuracy using the spectral angle mapper was 76%. The classification data were used to test the Weed Invasion Susceptibility Prediction (WISP) model, which uses available geospatial data layers to predict the potential distribution of various invasive weeds. Kappa analyses showed that the WISP model predictions were no better than chance. New parameters for the WISP model were developed and the accuracy of model predictions increased to 84%. The WISP model can be the basis for an invasive weed decision support system.

Integration of MODIS Products and a Crop Simulation Model for Crop Yield Estimation

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Keywords: crop yield, CERES-Maize, MODIS Leaf area index, vegetation index, data assimilation, optimization

A data assimilation approach is developed to integrate remotely sensed data with a crop growth model for crop yield estimation. Our objective is to improve the crop yield estimation using the MODerate Resolution Imaging Spectroradiometer (MODIS) products when the input data for the crop growth model are insufficient. The Cropping System Model (CSM)-CERES-Maize (Hoogenboom et al. 2004) and the Markov Chain Reflectance Model (MCRM) (Kuusk 1995) were coupled and different MODIS products were assimilated to estimate corn yield in Indiana, USA. These products include 1) the leaf area index (LAI); 2) either the normalized difference vegetation index (NDVI) or the enhanced vegetation index (EVI); and 3) both LAI and NDVI (or EVI).

In the data assimilation procedure, the outputs from the crop model (e.g. LAI) and other ancillary data (e.g. soil reflectance) were used in the canopy reflectance model to simulate top-of-plant reflectance. Vegetation indices (VIs) were calculated from the simulated reflectances. The simulated VIs and LAI were compared with the corresponding MODIS products and the residuals between simulated and MODIS LAI or VI were minimized by adjusting the input parameters for the crop model. With the optimized set of input parameters, the model was re-run to generate the crop yield information.

The estimated corn yield in 2000 was compared with the US Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) data and both agreed very well (Figure 1). Among different schemes, the best results were obtained when both MODIS VI and LAI products were assimilated and the relative deviations were less than 2%. The results from using only EVI or NDVI were unacceptable, as the deviations were as high as 21% and -13% for the EVI and NDVI schemes, respectively. The simulated LAI and VI seasonal profiles showed that the MODIS LAI, EVI and NDVI products overestimated during the beginning of the season by about 0.64, 0.248 and 0.254, respectively. The field hydrological conditions of the crop fields were also retrieved successfully.

The soil, weather, and crop parameter data sets developed for this study are useful guidelines for model application in other regions. The experimental procedure can be tested on a different set of agricultural environment and canopy characteristics. More rigorous evaluation is necessary to investigate the model's efficiency for other seasons and other crops.

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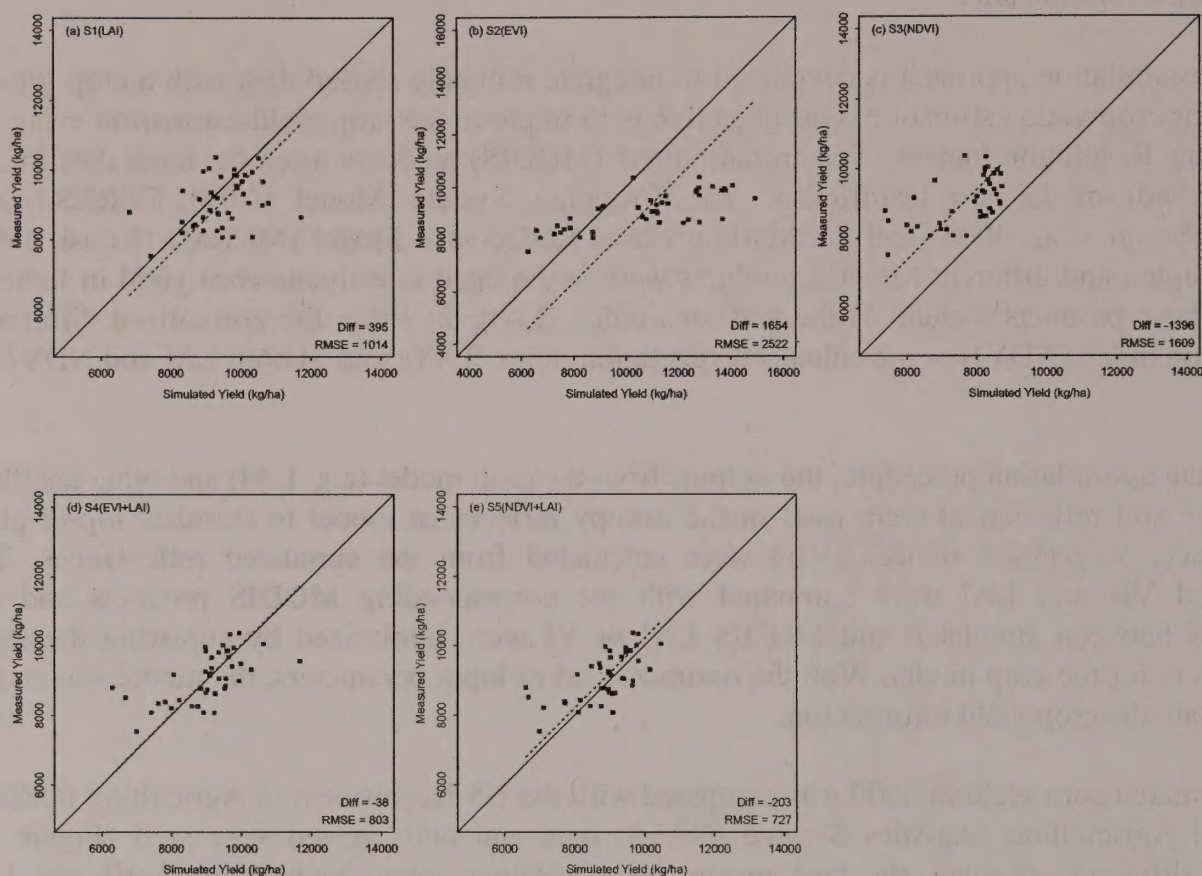


Figure 1. Comparison of the simulated corn yield and USDA NASS yield data for selected counties (43) in Indiana, 2000. (a) S1 (LAI); (b) S2 (EVI); (c) S3 (NDVI); (d) S4 (EVI+LAI); (e) S5 (NDVI+LAI). The abscissa and ordinate are the simulated and measured corn yield (kg/ha), respectively. The dashed line shows the mean offset indicated by "Diff". RMSE: root-mean-squared-error.

Modeling the Effects of Processed-Kaolin Particle Films on Gas-Exchange of Fruit Tree Leaves

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Processed-kaolin particle films are used on horticultural and agricultural crops to repel insects, and reduce heat stress and solar injury. Physiological benefits of the particle films include improved whole-plant carbon assimilation, water use efficiency, yield, and quality in horticultural crops (Glenn et al., 2003; Jifon and Syvertsen, 2003). A particle film changes leaf and canopy energy balances as a result of altered reflectance and transmittance in both photosynthetically active radiation (PAR) and near infrared radiation (NIR) (Doraiswamy and Rosenberg, 1974). These changes in radiation balances are likely the underlying mechanisms for the physiological responses that have been observed at both leaf and canopy levels. A mechanistic leaf gas-exchange model that couples biochemistry of photosynthesis, physiological control of CO₂ supply and water loss via stomatal conductance, and leaf energy balance can be an effective tool to understand how the optical properties and physiological processes of a leaf are influenced by particle films.

In the present study, a coupled model of photosynthesis, stomatal conductance, and transpiration previously developed for rose leaves (Kim and Lieth, 2003) has been extended to incorporate the effects of particle films on gas-exchange processes of fruit tree leaves. An empirically determined relationship between the concentration of particle spray and the optical properties of a resulting particle film was implemented to alter balances of PAR and NIR reaching the leaf surface. Model predictions were compared against experimental data of leaf gas-exchange. Additional factors that might be involved in how the particle films influence leaf physiological processes are discussed. Scaling considerations in modeling the effects of particle films on whole-plant and canopy processes are also discussed. The model can be used to identify the environmental conditions where particle films can be effectively utilized to mitigate the abiotic stresses on gas-exchange of fruit tree leaves.

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The first part of the study was a review of the literature on the development of brain tumors. This was followed by a description of the study design and the subjects. The results of the study are presented in the next section. The discussion and conclusions are presented in the final section.

The study was designed to investigate the effects of factors on the development of brain tumors. The subjects were divided into two groups: a control group and an experimental group. The control group consisted of 100 subjects, and the experimental group consisted of 100 subjects. The subjects were followed up for a period of 10 years. The results of the study are presented in the next section. The discussion and conclusions are presented in the final section.

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The Adaptability of the Soybean Model, GLYCIM, For Tropical Conditions

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Soybean (*Glycin max* L.) is an important legume crop for oil extraction in the tropical region. Several simulation models have been developed for a number of crop production processes including soil erosion, crop management, input optimization, growth and yield. The soybean model GLYCIM has been designed to simulate growth and development of soybean crop on any soil and at any location and time of year.

The main objective of this research was to study the adaptability of the soybean model, GLYCIM for tropical conditions. Field experiments were carried out at Asian Institute of Technology, Thailand with three different dates of sowing 245, 259 and 273 Julian days with three different varieties CM-2, SJ-5 and CM-60. For different treatments, inputs were defined and provided to the model. Predicted results were obtained and the model was tested for given treatments. It was found that the early sowing treatment (245 JD) gave significantly higher values of leaf area, plant height, dry matter and seed yield compared to the medium and late sowings. Cultivar SJ-5 showed significantly higher seed yield among all three cultivars at all sowing dates, followed by the cultivar CM-2. The model prediction of vegetative (Vstage), reproductive (Rstage), leaf area total and on main stem were close to the measured values. Plant height was slightly underestimated for early and medium sowing whereas overestimated for late sowing. The number of flowers, pods and seeds were shows slightly higher prediction for early and medium sowing while late sowing shows somewhat less. The prediction of shoot weight, seed weight and root weight per plant found to be closer to the measured values. The leaf area on branches shows underestimation for all three sowing dates whereas the seed yield seems to be considerably higher predicted for early sowing and lower for medium and late sowing. Nevertheless, GLYCIM does reasonably good job of prediction especially for the given cultivar and sowing dates for tropical conditions. This study revealed that the soybean model GLYCIM can be used for the tropical region with treatment combination of different sowing dates and varieties.

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Biological-Mathematical Models New Theorems

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Keywords: mathematical modeling, evapotranspiration, phylogenomics

This article is a survey of recent work in the mathematical and modeling applications for agriculture and to science in general. As one of the cites argues “in future interactions between mathematics and biology, both fields will contribute to each other, and, in particular, research in the life sciences will inspire new theorems in ‘pure’ mathematics” or agricultural engineering, the field of the author. This is a snapshot of recent contributions from biology to geometry, topology, Bayesian statistics, probability, combinatorics and algebra.

The author had the opportunity of attend the June 2005 public lecture on Physmatics by Clay Senior Scholar Eric Zaslow and the November 2005 workshop on Algebraic Statistics and Computational Biology organized by Lior Pachter, Seth Sullivan and Bern Sturmfels at the Clay Mathematics Institute in Cambridge [Clay, 2005, Pachter and Sturmfels, 2005]. These lectures and the work of J.L. Monteith in mathematics applied to biology and agriculture [Monteith, 1973] inspired this survey. There are many contributions of mathematics to biology and agriculture, could the reverse be possible? Gian-Carlo Rota wrote his widely quoted sentence, “The lack of real contact between mathematics and biology is either a tragedy, a scandal, or a challenge, it is hard to decide which” [Kac et al 1986, page 2]. Professor Rota has a well knowledge of the long history of mathematics helping biology, such as the development of population genetics by Fisher, Hardy, Wright and others in the early 1900’s [Bower and Bolouri, 2001; Murray 2002, 2003]. But Professor Rota conclusion was that no “real contact” exists. Physics remains the gold standard for mathematicians, and the three are used for agricultural engineers, modelers, etc. There has been “real contact” and mutual “collaboration” over a considerable period of time. Historically, mathematics has made many contributions to physics, and in the last twenty years there has been a payback beyond expectations. Many of the most exciting developments in current mathematics are a direct outgrowth of research in theoretical physics. Today’s geometry and topology, which some modelers use to study the topology of the root system [Sanchez and Vergara, 1993] are unthinkable without string theory, mirror symmetry and quantum field theory. There is not doubt hat physics can lead to new theorems. At the June 2005 public lecture on Physmatics by Clay Senior Scholar Eric Zaslow sums up the situation as follows: “The interplay between mathematics and physics has, in recent years, become so profound that the lines have been blurred. The two disciplines, long complementary, have begun a deep and fundamental relationship...”[Clay, 2005]

The author thinks that DSSAT ® is doing the same for agriculture; using mathematical models with biological implications, the borders had been blurred. The new “science” of Agro-Bio-Physmatics has born. To start the technical discussion the author wants to use a basic definition: Potential Evapotranspiration [Penman, 1948] is defined as the amount of water transpired in unit time by a short green crop, completely shading the ground, of uniform height and never short of water. Penman, a physicist, started his equation from the Dalton equation for evaporation from a saturated surface. $LE = (e_s - e) f(u)$, where u is the wind speed above the surface, e_s is the saturation vapor pressure (absolute humidity) at the temperature of the surface, e is the vapor pressure of the air above the surface at an elevation sufficient so that e is unaffected by e_s . Through physical and algebraic rearrangements this equation becomes: $LE = ((\Delta/\epsilon) J_n + LE_a) / (\Delta/\epsilon + 1)$, this equation generated a boom of similar equations over the world.

J.L. Monteith [1973, 1980, 2004] a PhD mathematician, turned in a PhD agronomist [Feinstein, 1992] provided an extension of the Penman equation to include the transfer –resistance concept to account for heat and vapor transfers from less-than-saturated surfaces. The Penman- Monteith equation is one of the methods used by the physicists, agronomists, agricultural engineers, etc. To determine the potential evapotranspiration [Allen et al, 1998]. The author could include many material from DSSAT ® which has contributed extensively to biology and physics, statistics and mathematics, but instead invites to the interested reader to visit the website in the references. The author wants to determine activity of transcription factors by reverse transcription polymerase chain reaction (RT-PCR), and found the following theorems cited by Sturmfels [2005] and Deonier [2005] very useful, perhaps no easy to be program in a portable computer model.

“Theorem 1. (Dress-Bandelt Split Decomposition [Bandelt and Dress 1992]) Every finite metric space D admits a unique coherent decomposition $D = D_1 + \cdots + D_k + D'$, where $D_1, \dots, D_k$ are linearly independent split metrics and D' is a split-prime metric. This theorem is useful for evolutionary biology because it offers a polyhedral framework for phylogenetic reconstruction. It can be computed using the software POLYMAKE. [Joswig] Note that, for larger data sets, the tight span is often too big. This is where Theorem 1 enters the scene: what one does is remove the splits residue D' from the data D . The remaining split-decomposable metric $D_1 + \cdots + D_k$ can be computed efficiently with the software SPLITSTREE due to Huson and Bryant [2006]. It is represented by a phylogenetic network.”

“Theorem 2. (Pachter-Speyer Reconstruction from Subtree Weights [Pachter and Speyer, 2004]). Suppose that $n \geq 2m-1$. Every phylogenetic tree on n taxa is uniquely determined by its subtree weight function. More precisely, $\delta^{T,m}$ determines the tree metric $\delta^{T,2}$. The punchline of this theorem is a statistical one. The aim of replacing $m = 2$ by larger values of m is that $\delta^{T,m}$ can be estimated from data in a more reliable manner. Practical advantages of this method were shown in [Levy et al, 2006]. Phylogenetics has spawned several different research directions in current mathematics, especially in combinatorics and probability [Semple and Steel, 2003]”

“Theorem 3. (Buczynska-Wisniewski Flat Family of Trees [Buczynska-Wisniewski]) The abstract of their preprint leaves no doubt that this is an unusual paper as far as mathematical biology goes: “We investigate projective varieties which are geometric models of binary symmetric phylogenetic 3-valent trees. All toric varieties X_T are the same connected component of the Hilbert scheme of projective schemes, as T ranges over all combinatorial types of trivalent trees with $n + 1$ leaves. Combinatorially, this means that the convex polytopes associated with these toric varieties all share the same Ehrhart polynomial (a formula for this Ehrhart polynomial is given in [Buczynska-Wisniewski, §3.4])

“Theorem 4. (Elizalde-Woods’ Few Inference Functions) [Elizalde and Woods, 2006; Elizalde, 2005]) Consider a graphical model G with d parameters, where d is fixed, and let E be the number of edges of G . Then the number of inference functions of the model is at most $O(E^{d(d-1)})$. This concludes my discussion of a definition and four recent theorems that were inspired by biology and physics.

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Notes

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HENRY A. WALLACE

Commemorative Ceremony



Henry A. Wallace
Beltsville Agricultural Research Center
Beltsville, Maryland

Agricultural Research Service
U.S. Department of Agriculture

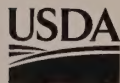


HENRY A. WALLACE



Agricultural
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U.S. Department
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A Pigment of the Imagination



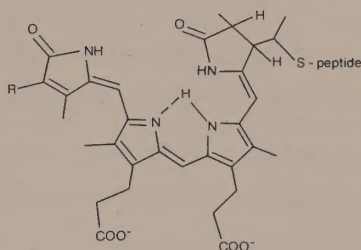
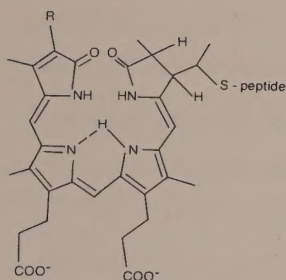
USDA AND THE DISCOVERY OF
PHYTOCHROME



Title page: Structures of the red-absorbing and far-red-absorbing forms of phytochrome, P_r and P_{fr} , according to current knowledge. Only the chromophore, or light-detecting portion of the molecule, is shown in detail. Application of red light converts P_r into P_{fr} ; application of far-red light converts P_{fr} into P_r . These structural changes in the chromophore alter the activity of the protein portion of the molecule, which in turn controls many aspects of plant development.

A Pigment of the Imagination

USDA AND THE DISCOVERY OF PHYTOCHROME



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BE IT ENACTED . . . That there is hereby established at the seat of Government of the United States a Department of Agriculture, the general designs and duties of which shall be to acquire and diffuse among the people of the United States useful information on subjects connected with agriculture in the most general and comprehensive sense of that word, and to procure, propagate, and distribute among the people new and valuable seeds and plants. . . . it shall be the duty of the Commissioner of Agriculture to acquire and preserve in his Department all information concerning agriculture which he can obtain by means of books and correspondence, and by practical and scientific experiments (accurate records of which experiments shall be kept in his office), by the collection of statistics, and by any other appropriate means within his power. . . .

—Act of Congress signed by

President Lincoln on May 15, 1862

A Pigment of the Imagination

USDA and the Discovery of Phytochrome

From its birth, the United States Department of Agriculture has had among its duties the advancement of our understanding of plant life, on which all human life ultimately depends for sustenance. The many practical investigations it has carried out over the last 125 years have contributed greatly to the current preeminence of American agriculture. However, one of the USDA's most renowned and far-reaching contributions to knowledge was the result of a sustained effort in basic research. Working over a period of three decades, a small group of USDA scientists deduced the existence of a pigment that nearly all plants use to adapt their behavior to the light in their environment, and then determined its chemical nature and isolated it in a test tube. Phytochrome, as they subsequently named the pigment, acts as a universal regulator in plant life; it senses the quality of the surrounding light and in the process exerts a strong control on such essential activities as seed germination, stem and leaf growth, and reproduction. At one time suspected by other researchers to be a "pigment of the imagination," the elusive molecule was tracked down in a collaboration among several basic and applied laboratories at the Agricultural Research Center in Beltsville, Maryland. This is the story of a landmark achievement in the history of the USDA, and in modern biology: the discovery of phytochrome.

The Case of the Seedless Tobacco

The story begins in 1906 in a Maryland field, where a remarkable mutant tobacco plant was found growing. Unlike the standard tobacco varieties, which would put out a limited number of leaves and then flower and go to seed, the mutant grew vigorously until it was killed by frost, reaching a height of 15 feet and producing as many as 100 leaves. Maryland Mammoth seemed to be a godsend to

tobacco farmers, except for one other characteristic: it seldom flowered and never produced mature seed in the field. Seed could be obtained only by growing the plants in the greenhouse during winter, and this severely limited the variety's availability.

In 1918, two lifetime USDA scientists, physiologist Wightman W. Garner and botanist Harry A. Allard of the Tobacco Division, Bureau of Plant Industry, were puzzling over this problem and one other: soybean farmers had been reporting that when they tried to space out their harvests by planting every two weeks, all the plants flowered and set seed at the same time. The conventional wisdom of the day was that there were two main influences on plant growth, namely soil and climate, and that seasonal changes in temperature were the most important factor. Garner and Allard undertook some detailed experiments and found that temperature, moisture, mineral nutrition and light intensity had only minor influences on the flowering of tobacco and soybeans. As Garner later recalled, the only factor left was the relative length of night and day. "The decisive test was then made in the simplest possible way but without great hope of success, mainly for the reason that there appeared to be no accepted basis in plant physiology for consideration of day length as other than a purely quantitative factor."

In July of 1918, Garner and Allard began the simple, decisive test. They subjected some potted tobacco and soybean plants to a drastically shortened day by moving the plants from the field into a windowless shack in the afternoon, and replacing them in the sun the next morning. The Maryland Mammoth tobacco plants flowered two months into this regime, some three months earlier than control plants left in the field continuously; the test soybeans flowered five weeks earlier than their counterparts in the field. The length of day was indeed the critical factor that determined when these plants flowered.

Subsequent experiments showed that different plants require different proportions of daylight and darkness in order to flower and set seed. Some, like Maryland Mammoth tobacco, Biloxi soybean, chrysanthemum, and poinsettia, are "short-day" plants that flower in the spring or fall; others, like spinach, lettuce, and potato, are "long-day" plants that flower in summer; still others, like tomato and dandelion, are "day-neutral" and flower in any season. Generally, plants that come from tropical areas require short days, and plants whose homes are closer to the poles require long days in order to flower.

The practical consequences of this USDA research have been enormous, and are now taken for granted. Florists began to use artificial light regimes to assure year-round supplies of popular flowers that were once strictly seasonal. Farmers became aware of the importance of planting at the appropriate time to avoid premature flowering, and using varieties suited to their latitude; soybean varieties, for example, could suffer noticeably if planted 100 miles north or south of their optimum. And plant breeders began to develop and test their new varieties at will indoors rather than waiting to grow one crop a year in the field. As for Maryland Mammoth, its seed crop was soon being grown in the fields of southern Florida during the short days of winter.



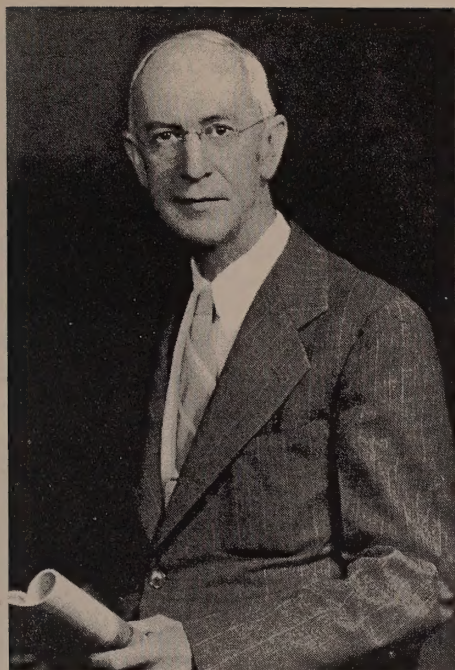
Two of the Maryland Mammoth tobacco plants with which Garner and Allard confirmed the influence of daylength on plant behavior in the winter of 1919. The plant at left was grown in an unlighted greenhouse on short days and has flowered. The plant at right was supplemented with several hours of artificial light, and continues to produce new leaves.

The Beginnings of Basic Research in Photoperiodism

Garner and Allard gave the name *photoperiodism* to what they described as "the response of an organism to the relative length of day and night." As their other duties permitted, they continued to study its manifestation in a variety of plants for many years. Then in 1935, through the Bankhead-Jones Act, Congress provided significant new funds for the Department of Agriculture "to conduct research into laws and principles underlying basic problems of agriculture in its broadest aspects." The following year, a small research project devoted specifically to the study of photoperiodism was established at the recently reorganized Agricultural Research Center at Beltsville, Maryland. The initial idea was to approach the mechanism of photoperiodism through detailed study of the structural changes induced in plant tissue as it gives rise to reproductive organs, and the physiological processes that cause those changes.

Harry A. Borthwick, a 38-year-old botanist at the University of California, Davis, was chosen to head the project. A native of Minnesota, he had received his Ph.D. from Stanford University in 1930 for a detailed morphological study of the development of the carrot embryo, which demonstrated that the large failure rate in the germination of carrot seeds was due to defects in the embryos. At Davis he completed a classic work on the development of the lettuce seed, from fertilization of the ovum to seed maturation. A quiet, shy man but a determined scientist, Borthwick brought to the project a broad knowledge of plant development, an attentiveness to minute details of structure, and an interest in agricultural applications of basic research. Joining Borthwick as associate physiologist was Marion W. Parker, a 29-year-old assistant professor at the nearby University of Maryland, where he had also earned his doctoral degree and studied the chemical composition of sweet corn, snap beans, and squash. His initial task at Beltsville was to investigate the influence of nutrition on photoperiodism. Parker had a ready smile, a quick wit, and something of a temper; he proved to be a first-rate experimentalist.

Borthwick and Parker began by consulting with the discoverers of photoperiodism. As Borthwick recalled in 1972, for the first several years of the project "Garner and Allard were still active and although our projects were administratively separate we actually enjoyed close relations with them and profited greatly by their advice. Mr. Allard's suggestion as to a suitable plant with which to investigate control of



Wightman W. Garner and Harry A. Allard, discoverers of photoperiodism

flowering was first that it be a short-day one," since that type was more precise in its response to photoperiod. Allard particularly recommended the Biloxi soybean, which had been among the varieties he and Garner had first tested. Accordingly, most of the studies of the next decade were done on Biloxi soybeans. Wintex barley was chosen for comparison as a representative of plants that require long days and short nights to flower.

Borthwick and Parker published fourteen papers in the *Botanical Gazette* over the six years from 1938 to 1943. The hallmark of this initial work is a rigor and precision of approach that was rare in the field, and essential to any real progress. Many earlier studies had been content to use the obvious appearance of flowers as proof of the photoperiodic induction of reproductive growth, but Borthwick realized that microscopic flower primordia might have been present before any photoperiodic stimulus, or conversely that primordia might be induced and yet fail to develop beyond some early, minute stage. He and Parker accordingly undertook the fundamental spadework of determining the first real morphological changes caused by a



Marion W. Parker and Harry A. Borthwick. At the Plant Industry Station, around 1940.

change in photoperiod, exactly when they first became detectable, and precisely what kind of stimulus was required. By means of thousands of laborious dissections and microscopic studies, they established that only two short photoperiods were sufficient to induce flowering in Biloxi soybeans, and that the first flower primordia were detectable after only 5 days. By covering different parts of the plant with black cloth, they were also able to confirm reports that the stimulus was received not by the growing shoot tips where the flowers would actually form, but by the leaves. The influences on photoperiodism of plant age, temperature, leaf position, photosynthetic activity, and grafting were the focus of other experiments, some of them carried out by junior physiologist Peter H. Heinze.

In 1937 or 1938, Borthwick and Parker discovered a phenomenon that would prove critical to their future efforts. The first report was made in 1938 by Karl Hamner and James Bonner, who worked with the short-day weed cocklebur; for some reason, the Beltsville team never published their observations at the time. The short-day Biloxi soybean would flower if it experienced long nights of at least 10.5 hours. However, Borthwick and Parker found that flowering could be prevented if the long night was interrupted by a single, low-intensity illumination lasting as little as 30 seconds. An ordinary light bulb was sufficient. For horticulturalists, this observation would mean lower electrical bills; flowering could be delayed by exposing plants to a flash in the night instead of hours of additional full illumination. For research in photoperiodism, it would mean a clearer distinction between the influence of light quality and duration and the influence of light quantity. Without the dark interruption, Borthwick and Parker would be limited to testing with hours of intense light, which also affects a plant's energy production and general growth, and then waiting several days for the plant's response, during which time the plant could change in many irrelevant ways. With the dark interruption, they could instead apply a dim, brief flash of light that would have few side effects, and expect with some justification that the initial response would be very rapid. That is, Borthwick and Parker now had a sharper scalpel with which to dissect the mechanism of photoperiodism.

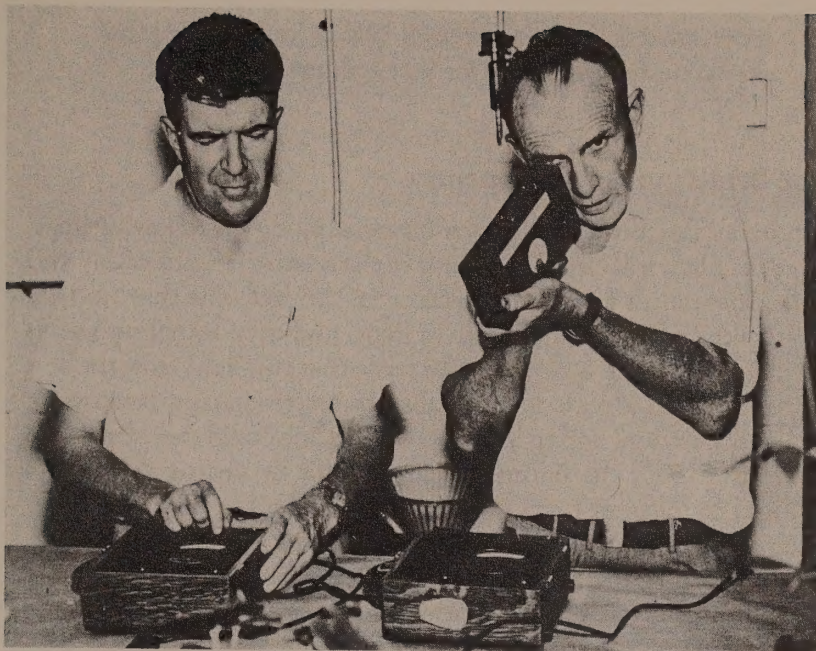
An Authority on Light Joins the Project

During the 1930s and 1940s there were several other laboratories in the world studying the photoperiodic control of flowering. Most of

them focused mainly on the observation that some sort of signal must be transmitted from the leaf to the growing shoot tip, and were intent on identifying that signal. Especially influential was the Russian scientist M. Kh. Chailakhyan's postulation of a specific flowering hormone, which he named "florigen." Parker and Borthwick, however, had serious doubts about the experimental usefulness of this hypothetical approach. They decided that a more likely path to progress would be to scrutinize the initial event in the photoperiodic response: the interaction of light with the plant leaf. The history of plant science has borne out their intuition; a "florigen" has yet to be found. Borthwick and Parker were also realistic enough to recognize their own weaknesses. They knew leaves very well, but they did not know enough about the properties and experimental use of light. Accordingly, they sought out an eminent colleague in the Agricultural Research Service who was expert in the experimental applications of electromagnetic radiation.

Sterling B. Hendricks was born in Texas in 1902 and received his Ph.D. in chemistry from the California Institute of Technology, where he was Linus Pauling's first graduate student and among the first Americans to apply X rays to the study of molecular structure. He made an impression on Pauling as "a keen and lively young fellow, full of energy. With his straw-colored hair and freckles, he reminded me of Peck's Bad Boy." "Even though he was not a small man, I continue to think of him as a pixie, perhaps because of the memory I have of him as he demonstrated an unusual muscular control—that of wiggling his ears alternately, so that his scalp executed a harmonic motion from side to side." Outside the laboratory, Hendricks devoted his energies to serious mountaineering. During the 1930s he climbed four previously unscaled peaks in the British Columbian Rockies, and in 1942 was a member of the third party to reach the top of Mt. McKinley.

At Caltech and during two postdoctoral stints, Hendricks determined the crystal structures of several minerals and simple organic compounds. In 1928 he was recruited by F. G. Cottrell to join the Fixed Nitrogen Laboratory of the Department of Agriculture. Hendricks spent the rest of his professional life in USDA soils laboratories, where he did much to elucidate the complex structure of clays and the mechanism of ion exchange, a major factor in soil fertility. He was also a pioneer in the analysis of molecular structure by means of infrared spectroscopy, which is now a standard and essential technique, and made important contributions to our understanding of the hydrogen bond.



Harry Borthwick and Sterling B. Hendricks. Around 1950.

Hendricks has described the beginnings of his informal collaboration with the photoperiodism project, which would last for nearly thirty years.

In the early 1930s, H. A. Allard and W. W. Garner displayed some branched poinsettias with flowering controlled differently in the two branches by darkening. I saw the exhibit, more by accident than purpose, and thought the flowers pretty, but was innocent of any idea of ever being concerned with what went on. It was not until 1940 that Harry Borthwick and Marion Parker, who were taking up where Allard and Garner had left off, looked me up as a fellow employee of the USDA to discuss light action as it might possibly be involved in photoperiodic control of flowering. The course, all agreed, was to measure action spectra, which might be done by pooling abilities and access to materials. The rationale was that where light is involved in a phenomenon, an absorbing pigment must be functioning in some way. World War II

intervened and it was not until 1945 [actually, 1944] that preparations were made for an experiment.

The Strategy: Action Spectra

Hendricks, Borthwick and Parker reasoned along the following lines. Since the plant leaf clearly responds to the relative lengths of day and night, there must be some substance in the leaf cells that initially registers the presence or absence of light, and then somehow passes the information on. It would make sense that this light receptor be a pigment, a kind of molecule that absorbs certain narrow portions of the light spectrum, and so is itself colored. One could therefore learn something about the nature of the receptor by testing the plant's response to different parts of the spectrum. This is what an action spectrum is: a measurement of the organism's response, or action, when exposed to different portions of the electromagnetic spectrum.

The idea was fairly straightforward, but the practical details were daunting. Most spectrographic work of the time was done on very small samples of purified substances, not on whole plant leaves; and the light intensities were geared to the use of sensitive photographic films, not to the requirements of living plants. The initial white light source for the action spectra would have to be quite powerful so that, when it was dispersed into its component wavelengths, there would still be enough energy to have an effect on the plant. And the dispersion itself had to be very great, so that a whole leaf would be exposed to a very narrow band of wavelengths; nothing would be learned if several different colors fell on the same leaf. No existing spectrograph of the time came close to meeting the requirements.

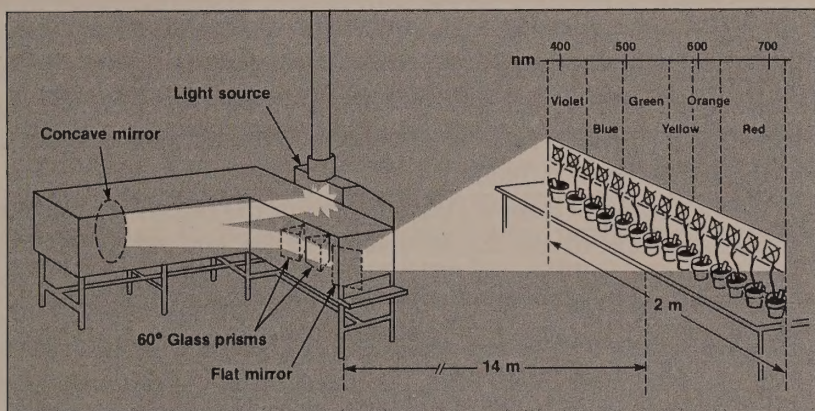
Hendricks himself designed the spectrograph. The economies of wartime meant dealing with some unlikely suppliers, but he and the shops at the Plant Industry Station made rapid progress.

The requirement on the light end centered in an adequately powerful spectrograph. It was met by using parts from the infrared spectrograph of the H-bond work, particularly the unusually large glass prisms which Langley, of aeroplane fame, had once used in work on the bolometer. The necessarily powerful carbon arc light source was cadged from a Baltimore movie theatre, with memories of pulchritude. The DC motor-generator was scrounged from elsewhere in the USDA, and the large

series resistance was one discarded by the Georgetown streetcar system upon changing from DC to AC operation. Everything was ready from scratch in two months with an outside cost of about \$50.

The spectrum from this unique instrument travelled some 14 meters from the last optical surface to the focal plane, where it was 10 centimeters wide and over 2 meters long, from violet on one end to the far red on the other. Fourteen plants could be accommodated at one time. The large focal length resulted in a spectral purity greater than that of most modern analytical instruments. The 10-kilowatt projection lamp made it possible to attain intensities at the focal plane on the order of one one-hundredth the intensity of full sunlight.

The experimental procedure was as follows. Biloxi soybeans were grown up in the greenhouse on long 16-hour days so as to prevent flowering. Plants that were selected for their similarity to each other were moved to a controlled environment room for several more long days. All leaves were then removed except the youngest mature one, which Borthwick and Parker had previously determined to be the



A schematic drawing of the spectrograph designed by Sterling Hendricks, and the plan of experiments that determined the action spectrum for the inhibition of flowering in soybeans.

most sensitive to photoperiod. The daylength was then decreased to 10 hours, which would normally induce flowering. At the middle of the dark period, the single leaf on each plant was exposed to a particular portion of the spectrum and for a particular length of time, which ranged from 1 to 25 minutes. Each plant was therefore given a different wavelength of light and a different total dose of energy at that wavelength. After six days of this regime, the plants were returned to long photoperiods. A week later, they were dissected and the number of flower primordia determined. The smaller the number of primordia that had formed on a given plant, the more effective the corresponding wavelength and energy of the dark-period interruption had been at inhibiting the flowering process—and presumably the more effective they had been at influencing the supposed receptor pigment.

The First Clue: Red Light Is Most Effective

After more than a decade of anecdotal and often contradictory reports on the importance of different wavelengths for photoperiodic effects, the Beltsville group was now in a position to make the first systematic and quantitative findings on the subject. Parker, Hendricks, Borthwick and associate physiologist N. J. Scully published a preliminary report of their results in the August 10, 1945 issue of *Science*. They found that "Floral initiation can be suppressed by interruption of the dark period with light of sufficient energy from any part of the visible spectrum, but there are two regions of maximum efficiency, one in the yellow, orange and red and the other in the violet." At last they had a crude fingerprint for the unknown pigment: since it probably absorbed strongly in the yellow-red region, it must itself be green or blue.

Of the two major classes of plant pigments, the Beltsville group was immediately able to rule out the yellow, orange, and red carotenoids as the photoperiod receptor. Their initial speculation was that it was instead "a porphyrin-like material which is probably chlorophyll," the photosynthetic pigment whose absorption spectrum had several features in common with the action spectrum. A year later they published a more extensive study that included both soybean and cocklebur, and the similarity of the action spectra indicated that the same pigment or pigments were involved in these two unrelated short-day plants. Again, chlorophyll was discussed as the prime suspect.

Over the next several years, evidence slowly mounted that the Beltsville group was on the trail of something fundamentally important to the entire life cycle of most plants. In 1948 they showed that Wintex barley, a plant that requires long days to flower, could be induced to flower during a short-day regime by briefly interrupting the dark period with dim light: and red light was most effective. This was the first evidence that flowering in both long-day and short-day plants is controlled by the same receptor molecule. The next year, working with Frits W. Went of the California Institute of Technology, they showed that if pea seedlings are grown in the dark and then exposed to light, the subsequent shift in vegetative growth—the enlargement of leaves and inhibition of stem lengthening—showed the same wavelength dependence as control of flowering. Both young plants and old plants, vegetative growth and reproductive growth, appeared to be regulated by the same light receptor. This in itself was a revolutionary finding.

Over the same period, further study of these action spectra indicated that the receptor was probably not chlorophyll. Instead, a suggestive resemblance was found to the absorption spectrum of phycocyanin, a blue pigment found in algae, and in 1950 Parker, Hendricks and Borthwick first proposed that the receptor pigment “might be some type of straight-chain pyrrole.” They were right, but it would take them 15 years to prove it.

By this point, the project had accumulated clear evidence that a single receptor molecule was involved in the light control of flowering and normal growth in a variety of very different plants. And there were tantalizing clues as to the chemical family to which the receptor might belong. However, the investigation was limited by the fact that its tests for the presence of the receptor were awkward, time-consuming, and not very precise: the plants took weeks to grow and several days to show an effect, and the spectral regions involved were rather broad. In the jargon of the biochemist, further progress would require a better assay for the receptor. Once again, informal help from another USDA laboratory brought the necessary advance.

Far-red Reversal: The Receptor Is a Biological Switch

Immediately adjacent to the room housing the action spectrograph was the Seed Investigations laboratory of Eben H. and Vivian K. Toole, who had long been interested in the fact that some seeds need

to be exposed to light before they will germinate. As it turned out, in 1934 Eben Toole had asked a staff physiologist, Lewis H. Flint, to study this phenomenon; and Flint, in collaboration with E. D. McAlister of the Smithsonian Institution, had found that red light was most effective at promoting germination in lettuce seed. Eben Toole brought this parallel phenomenon to the attention of Borthwick and Hendricks at some time in 1951 or early 1952, and proposed studying the action spectrum for the promotion of lettuce-seed germination.

This collaboration turned out to be more productive than anyone could have anticipated. In the first place, the action spectrum for seed germination matched those for flowering and the growth of stems and leaves. Here was yet another essential plant function that was controlled by the photoreceptor. Moreover, germination was much more convenient to work with than flowering or vegetative growth. The experiments could be done in a few days rather than a few weeks. The seeds could be taken off the shelf and "imbibed" in water for about 16 hours, exposed to the test light for a few minutes, and then checked for germination only two days later.

Most important of all, Flint and McAlister had noticed something about seed germination that Borthwick, Hendricks and Parker had failed to notice about flowering, but that would prove to be true for flowering as well. Far-red light—radiation just beyond the red limits of our vision—did not just fail to promote germination, it actively inhibited germination. The influence of far-red light is *antagonistic* to the influence of red light. This finding proved to be essential to all subsequent attempts to isolate and study the photoreceptor.

The five USDA scientists confirmed Flint and McAlister's general observation about far-red radiation and immediately extended it greatly. In a study dated June, 1952, they reported that seeds that were briefly exposed to red light germinated; if the red light was immediately followed by a brief far-red irradiation, the seeds failed to germinate. But if the far-red treatment were followed again by red light, the seeds germinated. Germination was determined simply by the last in a series of alternating treatments; this was true even if the number of treatments reached 100. This was the first evidence for the fact that the initial photoreaction is *reversible*. Additional information suggested that the effect of red and far-red light is to convert a single pigment from one form to another. It looked as though the pigment acted as a switch: it could be turned on or off, and only its final position mattered.



Vivian K. Toole and Eben H. Toole of the Seed Investigations laboratory

The next question was obvious: is the photocontrol of flowering also reversible? Just three months after their study of germination, Borthwick, Hendricks and Parker submitted a paper that was meant to remedy "inadequacies in previous work, chiefly by us, on action spectra for floral initiation." They confirmed that the inhibition of flowering by a brief red-light treatment of cocklebur could be reversed by a far-red treatment, and therefore that studies of lettuce-seed germination would probably be applicable to the other photoperiodic phenomena they had studied.

Borthwick, Hendricks and the Toolles published a more detailed study of the lettuce-seed system in 1954. It strengthened the case for a single pigment being involved and refined the experimental definition of the photoreaction they had been studying for nearly 20 years. The authors pointed out that because details of the action spectra for different plant materials would vary owing to differences in the other pigments and tissue structures, the single safest criterion for the photoreaction would be the mutual reversibility of red and far-red treatments. This became, and continues to be, the basis of tests for the presence of the pigment.

A Pigment of the Imagination

In 1952, just as the Beltsville group was unravelling the implications of photoreversibility, Marion Parker left the project to take on the first of a series of administrative positions that culminated in directorship of the Crops Research Division of USDA. "From that vantage point," Borthwick has said, "he continued to give strong administrative support to the laboratory until his death in 1966." Parker's advocacy was most evident in the USDA's decision in 1957 to designate the photoperiodism project a Pioneering Research Laboratory, which provided the group with its first operating budget. Parker's role in the laboratory was eventually filled by two young physiologists, Albert A. Piringer from the University of Minnesota and Robert J. Downs from George Washington University.

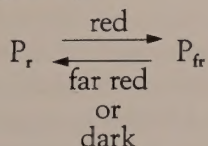


Marion Parker and Harry Borthwick. Around 1950.

During this extremely productive and exciting period of action spectrography, the Beltsville group had the field almost entirely to itself. Borthwick later remembered that "there was virtually no similar work in progress in any other laboratory and so we had the unusual experience for several years of working in an area in which practically no literature, other than our own papers, was produced." Unfortunately, this also meant that their work was not generally appreciated. Warren L. Butler, a biophysicist who joined the group in 1956, remarked that "most plant physiologists of the time did not believe that their subject matter was capable of revealing such molecular detail and, in the absence of direct proof, they were inclined to regard the pigment as a 'pigment of the imagination.'" Hendricks summarized the reaction to their prediction that the pigment was similar to phycocyanin: "The pronouncement was a dud, for few physiologists trusted anything found out by physiological methods—the demand was for a bottle of the stuff."

Warren Butler later reviewed this initial decade of work on action spectra and showed that the cool reception was understandable. The Beltsville group's detailed deductions about this otherwise unknown pigment were far from obvious at the time. They were indeed a product of the imagination. But the imagination in question was a collective, thoroughly scientific one, disciplined by long experience with plants and the effects of light on matter, and remarkably penetrating. Butler singled out for praise Hendricks's most important conceptual contribution:

His clarity of vision was even more apparent in the unprecedented proposal that the various effects of red and far-red light could be explained by a reversible, photochromic pigment which existed in two interconvertible forms, one absorbing red light, P_r , and the other absorbing far red light, P_{fr} :



... in retrospect, the proposed action of the pigment seems almost obvious, but in the context of the time at which it was made, this succinct hypothesis stands out as probably the boldest and most brilliant single stroke in the history of plant physiology.



Harry Borthwick and Robert J. Downs; Albert A. Piringer.
Around 1960.

A paper from 1956 shows especially well how the Beltsville group's physical and physiological imaginations could generate powerful insight when they played off each other. In 1955, the group had no solid information about either the chemical nature of the photoreceptor pigment or its concentration in plant tissues. Despite this, Hendricks saw a way of calculating minimum values for a fundamental physical property of the pigment: its extinction coefficients, or the efficiencies with which it absorbs the effective red and far-red wavelengths. Jack Downs had designed and carried out experiments on the behavior of dark-grown bean plants. He found that the subsequent growth of such plants depended in a quantitative way on the duration and intensity of red or far-red light supplied. As Downs recalls,

When enough results were in hand, Borthwick, Hendricks, Piringer and myself sat in conference to discuss their implications. Hendricks suggested that it appeared likely that we could obtain extinction coefficients if we could complete a more detailed response curve. This was easily done, and he proceeded to do the calculations.

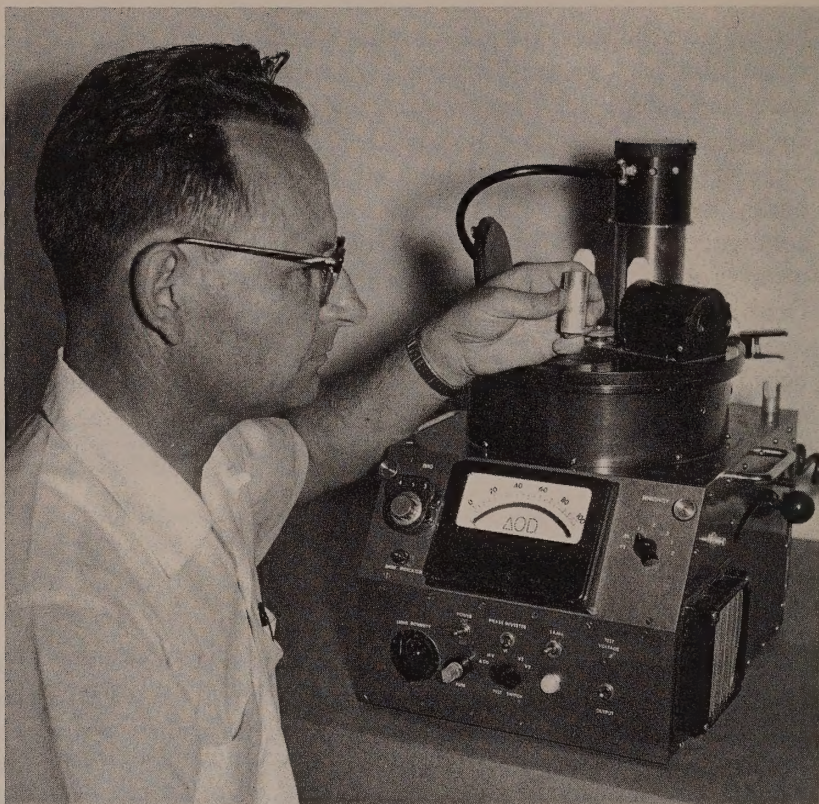
By determining the absolute energies required to achieve certain degrees of physiological response—the growth of dark-grown bean

plants and the germination of lettuce and pepper grass seeds—Hendricks was able to deduce that the extinction coefficients were quite high, some ten times those of chlorophyll, which meant that the pigment would be highly colored. The fact that not the slightest tinge of blue was visible in albino but photoresponsive mutants of barley indicated that the pigment was present in extremely low concentrations. This in turn led the group to propose that the receptor was a biological catalyst, or enzyme, and therefore a protein. Furthermore, because much less red light was required to switch the pigment to the far-red form than far-red light to do the reverse, and because red light initiated seed germination, they predicted that the enzymatically active form of the protein would be the far-red form. Every one of these deductions proved to be correct.

Important Assistance from the Agricultural Marketing Service

Armed with a definitive characteristic of the photoreceptor—the reversibility of red- and far red-absorbing forms—and with strong hunches about its other properties, the Beltsville group now set out to get “a bottle of the stuff.” This would require a major technical advance: translating the physiological assay into a direct physical one, so that the pigment could be detected by its spectral characteristics in the test tube as well as in plants. The primary obstacle was simple: the pigment is present in plants in very small amounts, just as the group had predicted. The plant’s physiological response is in effect an amplification of the pigment’s original action, and direct measurement of the pigment molecule’s own unamplified response proved elusive. A variety of different approaches were tried over a period of several years, and all failed to detect the pigment. Then for the third time in the history of the project, an informal collaboration with other USDA scientists brought the breakthrough.

Karl H. Norris was director of the Instrumentation Research Laboratory in the Agricultural Marketing Service, where he had gone after several years as an electronic engineer at the University of Chicago. He had worked for nearly a decade on nondestructive techniques for measuring the market quality of agricultural products, and developed several spectrophotometers that could measure the characteristic patterns of light absorption of dense, opaque materials. Ordinary spectrophotometry generally required that the material to



Karl H. Norris and the dual monochromator spectrophotometer, which the Beltsville group used for rapid and precise assays of phytochrome once they had detected it in plants. Photograph taken in 1962.

be tested be almost transparent; but Norris's innovative instruments were capable of handling such intact, opaque samples as eggs, apples, and even watermelons. The presence of a few blood cells could be detected in a defective egg without cracking it open, and the relative amounts of green chlorophyll and red anthocyanin pigments in the apple skin provided a measure of ripeness. The sensitivity of Norris's spectrophotometers, and their ability to handle intact plant tissue, were just the capabilities that Hendricks and Borthwick needed to detect the photoreceptor.

Two relatively new arrivals at Beltsville filled out the team that would finally lay its hands on the photoreceptor. Warren L. Butler,

who had recently received a Ph.D. in biophysics from the University of Chicago, joined Norris's laboratory in 1956 to work on chlorophyll and photosynthesis, and modified one of his spectrophotometers to handle the small, highly scattering samples of tissue that both he and the photoperiodism project would study. Butler made important contributions to the theory and technology of this kind of analysis, and later went on to a distinguished career that encompassed several areas of plant development and photosynthesis. His colleagues have also been impressed by Butler's rare personal qualities: he contended throughout his life with the effects of severe injuries sustained in World War II; and his sense of humor, abetted by a highly expressive eyebrow, was renowned.

The second new member of the team joined in 1957, when the Agricultural Research Service designated Borthwick's plant physiology laboratory as one of two Pioneering Laboratories for basic research (the other was Hendricks's mineral nutrition laboratory). Foreseeing the important role that biochemistry would play in future progress, Borthwick used his small increase in funding to bring Harold W. Siegelman to the project. Siegelman had received his Ph.D. in horticultural science from the University of California, Los Angeles in 1951 for work on the respiratory metabolism of flowers, and had already worked informally with Borthwick and Hendricks while in the postharvest physiology laboratory at Beltsville.

Warren Butler later characterized this remarkable assembly of expertise, which drew on three different USDA laboratories:

This group, consisting of a physical chemist, a plant physiologist, a horticulturalist turned biochemist, an agricultural engineer and a biophysicist, functioned in a rather loose affiliation without any administrative hierarchy. . . . the group had no "boss" as such. Our association was based solely on mutual interests and mutual respect for the integrity and scientific talents of the others.

Phytochrome in Hand

The basic idea guiding the group was this: because red light converts the photoreceptor into a form that is sensitive to far-red light, and vice versa, a treatment with red light should cause the pigment to absorb more in the far-red than in the red; and subsequent treatment

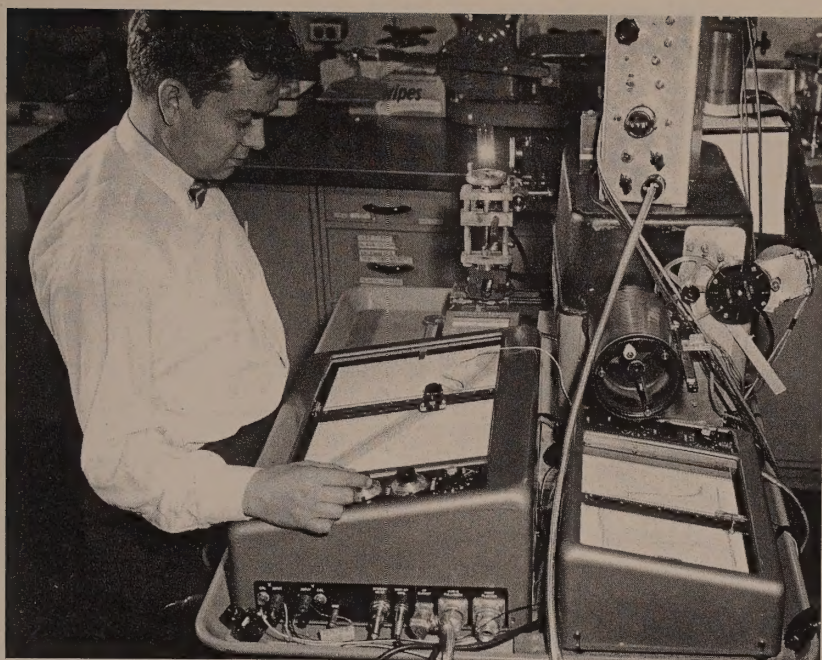
with far-red light should again make it more absorbant in the red. In other words, the spectrophotometer would register changes in light absorption by the plant tissue in the red and far-red regions following red and far-red irradiations of the tissue. In 1957 or 1958, Hendricks and Siegelman began visiting Butler and Norris with various materials to be tested in the spectrophotometer. The obvious first choices, lettuce seeds, cocklebur leaves and albino barley tissue, all failed to show any effect, and it appeared that the pigment might be present in concentrations too small to detect. But attempts continued with whatever new photoperiodic materials were available.

The breakthrough came in the middle of June, 1959. Warren Butler has described it.

Hendricks appeared in my lab one day with several Petri dishes of dark-grown turnip seedlings. We removed the cotyledons [the food-storage organs], pressed them loosely into the cuvette to a depth of about 1.5 cm and measured the absorption spectrum of the sample after irradiation with red and far-red light. To our amazement and delight, mixed with skepticism, we found that the difference spectrum between the red and far-red irradiated sample was precisely that predicted for phytochrome by the physiological action spectra.

Within two hours of the detection of the pigment in turnip tissue, Siegelman showed that a sample of ground tissue retained the spectral reversibility, and that boiling the sample destroyed the reversibility. This test was consistent with the prediction that the photoreceptor would be a protein. The events of this day have been called "a few of the most productive hours in the history of plant science." They were the culmination of twenty-three years of basic research.

At last, the Beltsville group had the stuff in a bottle. And the stuff needed a name, something more convenient than "the pigment controlling photoresponsive development of plants." Unfortunately, its precise chemical nature was not known, nor would it be for several years. According to Harry Borthwick, Warren Butler one day "half-jokingly" suggested the term *phytochrome*, from the Greek words for "plant" and "color." Despite the fact that the word had once been used to refer generally to all visible plant pigments, Borthwick and Hendricks officially proposed it in April, 1960. Upon purification, the red-absorbing form of phytochrome proved to be blue in color, and the far-red-absorbing form green.



Warren L. Butler and the single-beam spectrophotometer with which he, Norris, Hendricks and Siegelman first detected phytochrome in plants. Photograph taken around 1962.

Going Public

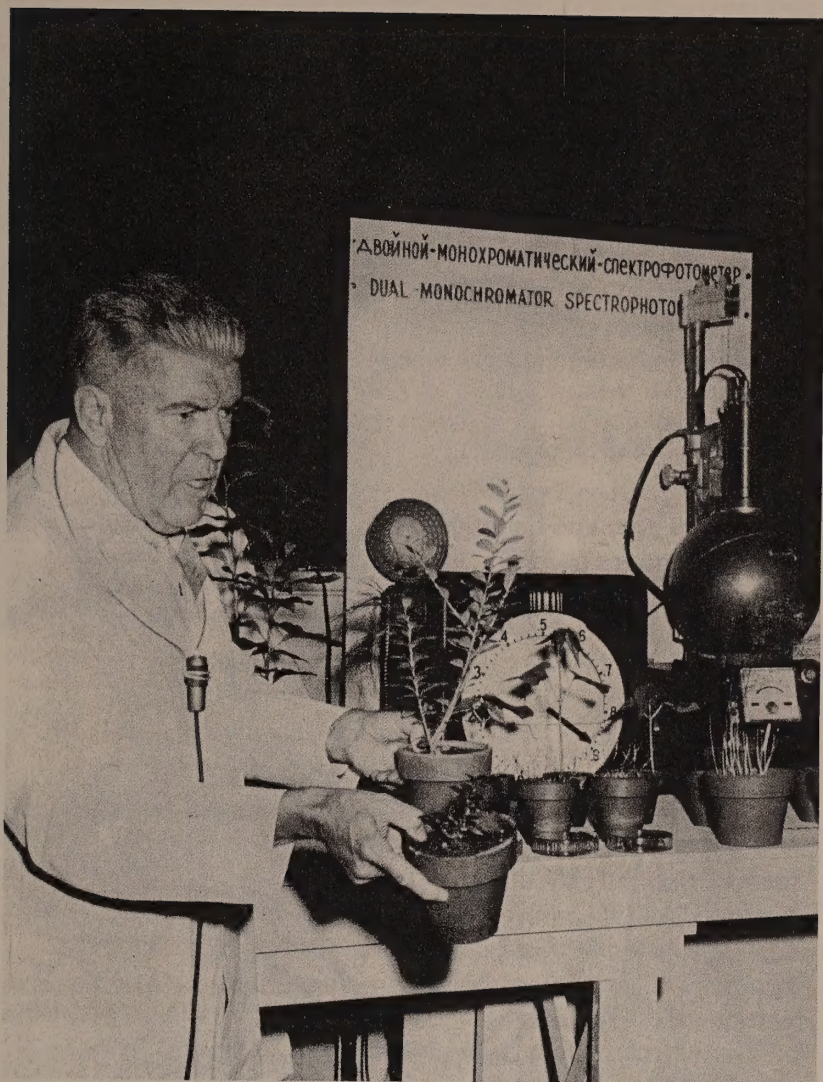
The first public announcement of the detection of phytochrome was a legendary fiasco that itself led to an important discovery. Hendricks had been invited to speak at the Ninth International Botanical Congress in Montreal in August, just two months after the first successful detection of the pigment, and he suggested that Butler give a demonstration at the end of his talk. Butler told the full story twenty years later.

Karl Norris soon produced a simple, easily transportable interference filter photometer in which the absorbance of a sample of short segments of dark-grown maize seedlings could be measured at 735 nm following irradiation with red and far-red light. The instrument was provided with a large circular meter (about the size of a large wall clock) with the sensitivity adjusted so that the meter

would swing between 9 o'clock and 3 o'clock following irradiation of the sample with red and far-red light. Numerous practice runs were made in preparation for Montreal and the measurement never failed. We left for Montreal in high spirits and with great expectations for the demonstration we had prepared for the botanical world.

We [Borthwick, Hendricks, Siegelman and Butler] drove to Montreal with the instrument and several clear plastic boxes of maize seedlings in the trunk of the car. On several occasions when stopping for gas someone would open the trunk to see how everything was riding. We arrived with everything apparently in good condition and set the instrument up just before the symposium started. Word spread that this remarkable (even mystical) pigment was finally in hand and would be demonstrated. The lecture hall was full. Hendricks talked for about 30 minutes giving background material and whetting the audience anticipation for the forthcoming demonstration and then turned the platform over to me. I described briefly what the instrument was going to measure, prepared the sample, irradiated it with red light and obtained the first reading which I zeroed to 9 o'clock on the meter. I then irradiated the sample with far-red light and again measured the absorbance. To my utter dismay the meter still read at 9 o'clock. I reirradiated with red and far-red light but the meter never moved. I rapidly prepared another sample only to repeat the failure. My brief scientific career flashed before me. There was little to be said; to affirm that it always worked before seemed hollow. However, in spite of the failure the audience appeared to be kind and accepting and even to believe that we probably had achieved what we claimed. The failure, however, was a complete mystery to us.

On their return to Beltsville, Butler and Siegelman salvaged an important lesson from that failure. They found that the far-red form of phytochrome is not stable; once generated in the seedling by exposure to red light, it is slowly destroyed. Every time that the trunk had been opened on the way to Montreal, the red-absorbing form was converted into the far-red form, some of which then disappeared. By



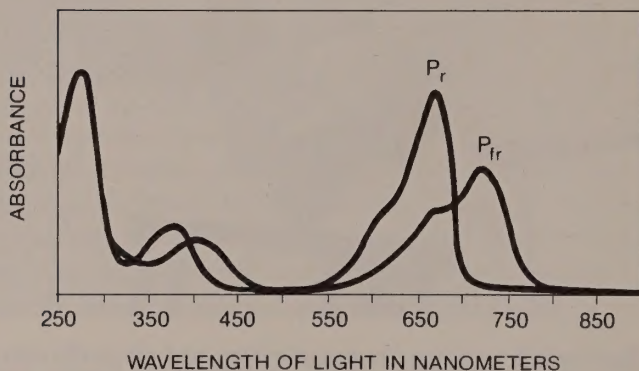
Harry Borthwick explains photoperiodism and phytochrome (before the pigment was given that name) to Soviet Premier Nikita Khrushchev during his visit to Beltsville in September, 1959. The clock-like meter display is the one that had failed to move at the International Botanical Congress in August.

the time of the demonstration, there was so little phytochrome left in the tissue that it could no longer be detected. This discovery of the dark destruction of P_{fr} , painful though it was, probably helped avoid complications in the subsequent work of purifying the pigment.

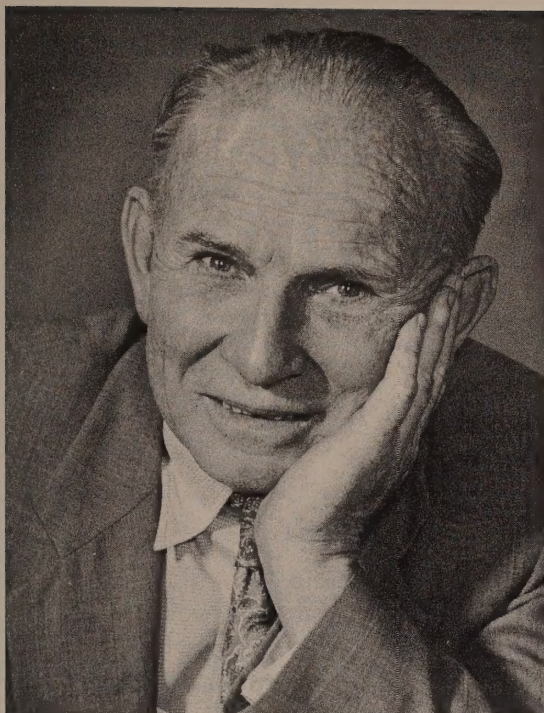
Butler, Norris, Siegelman and Hendricks published their landmark paper, "Detection, assay, and preliminary purification of the pigment controlling photoresponsive development of plants," in the December 1959 issue of *Proceedings of the National Academy of Science*. That paper ends with this sentence: "There would seem to be no essential barrier to finding the nature of the enzymatic action of the pigment, P_{735} , which constitutes the limiting pacemaker or 'bottleneck' of control evident in plant development and to elaborating physiological and biochemical aspects of its action."

An End and a Beginning

For once the Beltsville group's crystal ball was clouded. Today, nearly thirty years after the first extraction of phytochrome from plants, *how* phytochrome exerts its influence on plant development remains a mystery.



Absorption spectra of the red-absorbing and far-red-absorbing forms of phytochrome. The differences, and the fact that each form can be converted reversibly into the other, made it possible for the Beltsville group to detect the presence of phytochrome in plants and to purify it in the test tube.



Sterling Hendricks in 1960. The photograph was taken by plant physiologist Frank B. Salisbury.

There have been many obstacles to overcome. Bill Siegelman soon worked out techniques for purifying phytochrome with the newly developed chromatography media Sephadex and DEAE-cellulose, but it turned out that the protein is extremely susceptible to degradation by plant enzymes; and it was not until 1983 that later workers developed a fully reliable purification procedure. While Siegelman and Hendricks were able to confirm the prediction that the light-absorbing portion of the molecule, the chromophore, is a tetrapyrrole, and much subsequent research has established the precise structure, it has proven to be quite difficult to analyze the effects of red and far-red light on the chromophore, and the effects of chromophore changes on the protein portion of phytochrome. Major advances on this front have come just in the last year. It is still not known for certain where the biologically active phytochrome is located in plant cells, nor how it turns the various cellular machineries on and off. It definitely regulates the expression of some genes, including its own, but it can also have more immediate effects on plant behavior. In short, we are still a long way from knowing in detail

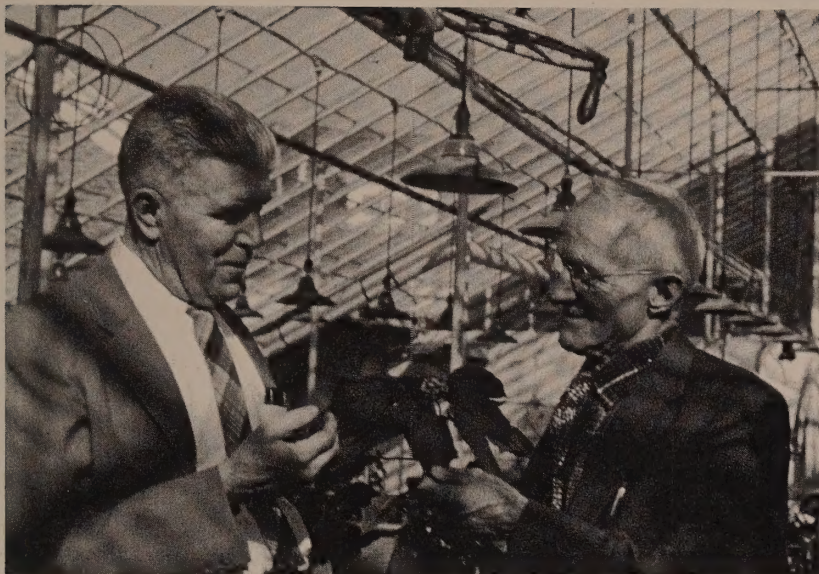
why Maryland Mammoth tobacco and Biloxi soybeans flowered when Garner and Allard shortened their exposure to daylight.

The lack of knowledge is not for want of trying. Today, some twenty or thirty major laboratories all over the world publish well over one hundred papers a year on various aspects of the subject, and they are making steady progress. For despite its difficulties, the study of phytochrome offers the promise of unparalleled access to fundamental processes underlying all of plant development, from seed germination to leaf drop. Once phytochrome action is understood, it may become possible to influence these processes artificially and precisely. Improved crop varieties and new methods for controlling growth are just two possible benefits of such knowledge. The story of phytochrome began in a field, and it will certainly return to the field.

To the dismay of scientists across the country, the USDA dissolved the Pioneering Laboratory of Plant Physiology in 1968, the year that Harry Borthwick retired and two years after the early death of its administrative advocate, Marion Parker. Harry Borthwick died in 1974, Sterling Hendricks in 1981, and Warren Butler in 1984. But long after its passing, the Beltsville group continues to exert a strong influence on phytochrome research. Its leaders provided the field with strong experimental and conceptual foundations. They personally trained many of the next generation of leaders, who came from all over the world to work at Beltsville. And they imparted more than technical expertise. Hans Mohr of the University of Freiburg, who was a postdoctoral fellow at Beltsville in 1957, later wrote:

The mode of cooperation among the Beltsville group opened my eyes to the benefits of team-work, and the wisdom, humility, and helpfulness of the two senior scientists was an unforgettable experience which has been a constant inspiration ever since.

The achievement of Borthwick, Hendricks, and their USDA colleagues is exemplary. It demonstrates the value of a broad approach to biological problems that ranges from the whole organism to the molecule; of cooperative efforts among diverse disciplines, basic and applied; of the full and imaginative use of resources and results; of steadfast institutional support. It is a story of American science at its best.



Representing two generations of USDA research in photoperiodism: Harry Borthwick and Harry Allard in 1960, shortly after the detection and initial purification of phytochrome.

Acknowledgements

Much valuable information about the Beltsville group and subsequent research on phytochrome was generously provided by Robert J. Downs, Karl H. Norris, Harold W. Siegelman, Winslow R. Briggs, Arthur W. Galston, and Peter H. Quail.

Photographs were kindly supplied by Robert J. Downs (pages 6, 9, 15, 16, 18, 29), Karl H. Norris (pages 20, 23), and Frank B. Salisbury (page 27).

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PREPARED BY HAROLD McGEE

DESIGNED AND PRODUCED BY KENNON-KELLEY GRAPHIC DESIGN

Activities Supported by FAR-B in 2015

- Provided judges and prizes for the Prince Georges and Montgomery County Middle School Science Fairs – Feb 2015
- Presented written testimony to Senate and House Agricultural Appropriations Subcommittees in support of the Beltsville Agricultural Research Center research programs, March 27, 2015
- Support the Student Discovery Garden
- Provided financial support for the Northeast Area Council of Office Professionals Team Building Workshop – March 11-12, 2015
- Handled registration WERA Conference
- Aileen Lee Award
- American Chemical Society
- Supported the Beltsville Diversity Taskforce Special Emphasis Programs
- Provided financial support and teaching assistance for the annual visit of the Maryland Agricultural Education Foundation Mobile Science Laboratory to the Beltsville Academy – October 27-30, 2014
- Supported Beltsville Poster Day – May 20, 2015 Provided refreshments and awards for the student interns
- Provided financial support for refreshment and materials for the Hispanic Serving Institutions Learning Experience – June 2-3, 2015

Activities and Events Supported in 2013

- Presented Written Testimony to Senate and House Agricultural Appropriations Subcommittee's in support for the Beltsville Agriculture Research Center Research Programs, March 20, 2013
- Presented 15 Certificates to Elementary Beltsville Academy Students for their posters they made after being in the MAEF Science trailer in October 2012, January 2013
- Supported the reaccreditation inspection of the BHNRC rodent facility by the Association for Assessment and Accreditation of Laboratory Animal Care (AAALAC), February 14, 2013
- Provided funds to support 5 Summer Intern Students for BARC Scientists – March 2013
- Helps support the Student Discovery Garden
 - Student Discovery Garden Learn at Lunch Seminar Series
 - "Honeybees, the wings of agriculture" March 15, 2013
 - "Native bees, everything you thought you knew was wrong" April 3, 2013
 - "What's in your backyard? Choosing plants to maximize ecosystem services" May 8, 2013
 - "Rising CO2 and bee health: exploring secondary effects of climate change" June 2013
- BARC Poster Day: Provided Refreshments, Lunches to All Participants and Presented Cash Awards to Top 3 High School Winners– April 16
- Supported the travel of a scientist to visit St. Petersburg, Russia to study the collection of *Trissolcus* wasps, potential biological control agents of the Brown Marmorated Stink Bug
- Judged Montgomery and Prince Georges County Middle Schools Science Fairs and presented 9 gift certificates to FAR-B winners in each County
- Provided lunches and Refreshments for 5th Annual Leaders of Tomorrow End of Summer Program and Activities – July 31
- Supported the printing of a brochure on the Brown Marmorated Stink Bug
- Supported travel to New Jersey in support of research on the Brown Marmorated Stink Bug
- Handled Registration Fees for 3rd Annual BARC-UMD Trends in Agriculture Annual Symposium: Climate Change, postponed till January 23, 2014 because of U.S. Government shutdown.
- Supplied refreshments for breaks for the International Conference:
 - "Sustainable Agriculture – Targeting Genetic Selection to Specific Environment and Management Circumstances (GxExM)" November 14

-
- The Beltsville Area Diversity Task Force Special Emphasis Programming
 - African American History Month Celebration – February 20, 2013
 - Women's History Month Celebration – March 21, 2013
 - Asian American Pacific Islander Heritage Month Celebration – May 15, 2013
 - Student Discovery Garden Season Opener and Fitness Walk – May 24, 2013
 - Beltsville Area Hispanic Serving Institutions Summit – Postponed until January 8 to 10 because of Government shutdown
 - National Gay and Lesbian Pride Month – June 2013
 - National Hispanic Heritage Month – September 18, 2013
 - National Disability Employment Awareness Month – Cancelled due to US Government shut down
 - American Indian Heritage Month – November 20, 2013

Activities and Events Supported in 2011

- Submitted testimony to US House and Senate Agricultural Committees in support of increased funding of research at BARC.
- Financial support to bring a Maryland Agriculture Education Fund teaching trailer to the Beltsville Academy - October 24 - 28, 2011.
- BARC Diversity Taskforce
 - International Food Festival and Fitness Walk with Student Discovery Garden Season Opener - May 5, 2011.
 - Purchased plants for the Student Discovery Garden - May, 2011
 - Asian Pacific Heritage Month - May 18, 2011.
 - National Gay and Lesbian Pride Month - June 15, 2011.
 - National Hispanic Heritage Month - September 21, 2011.
 - National Disability Employment Awareness Month - October 19, 2011.
 - American Indian Heritage Month - November 16, 2011.
- Graduate Student Agricultural Research Symposium - February 10 & 11, 2011
- Supported BARC Poster Day by supplying the tent, lunches, breaks, and cash awards for the top 3 High School Intern Projects - April 27, 2011
- Conservation Effects Assessment Project - Choptank River Watershed Project Tour - May 23, 2011.
- Financial support for three FAR-B Summer Internships.
- Secretary of Agriculture Vilsack visit to BARC- June 2011.
- Handled registration fees and paid bills for the Plant Germplasm Operating Committee meeting held at BARC - June 21-22, 2011.
- Leaders of tomorrow - End of Summer Student

Program - August 3, 2011.

- Provided refreshments for the Area Directors' Retreat at BARC - August 18, 2011.
- Purchased lunches when three Congressional Fellows of the American Veterinary Medical Association visited ANRI and met with ANRI scientists, August 29, 2011
- Handled registration fees for the BARC-UMD Fall Symposium - Trends in Agriculture - October 20, 2011.
- Handled registration fees and paid bills for the BARD Workshop "Micorarrays and Next-Generation Sequencing for Detection and Identification of Plant Viruses - November 17 - 19, 2011.
- Judged Montgomery, Howard, and Prince Georges County Middle Schools Science Fairs and presented gift certificates to FAR-B winners in 2011.
- Initiated membership in the Baltimore-Washington Chamber of Commerce"

National Restaurant Association Tours and Program
October 10, 2006

A. PROGRAM AND TOURS (1PM – 4PM)

1. ARS NUTRITION, FOOD SAFETY/QUALITY PROGRAMS AND RESOURCES

- **NATIONAL FOOD RESEARCH PROGRAMS**
Jim Lindsay – ARS National Program Leader – Food Safety; jal@ars.usda.gov
- **KEEPING FRESH PRODUCE SAFE AND TASTY**
Bill Conway – Acting Research Leader, Produce Quality and Safety Laboratory
conwayw@ba.ars.usda.gov
- **NATIONAL RETAIL MEAT SURVEY- IS AMERICAS MEAT SAFE?**
Dolores Hill – Research Parasitologist, Animal and Parasitic Diseases Laboratory
dhill@anri.barc.usda.gov
- **WHAT DO WE EAT IN AMERICA?**
Alanna Moshfegh – Research Leader, Food Surveys Research Group,
Beltsville Human Nutrition Research Center; amoshfegh@rbhnrc.usda.gov
- **FOOD AND NUTRITION WEB-BASED RESOURCES**
Dennis Smith – National Agricultural Library, Food and Nutrition Information Center
dsmith@nal.usda.gov
- **NEW ARS FOOD PRODUCT DEVELOPMENTS**
Martha Steinbock – ARS Office of Technology Transfer; martha.steinbock@ars.usda.gov

2. ARS BELTSVILLE HUMAN NUTRITION RESEARCH CENTER TOUR

- **HOW DO WE MEASURE WHAT AMERICANS EAT?**
Bill Rumpler – Research Physiologist; rumplerw@ba.ars.usda.gov
Valerie Elliott – Biological Lab Technician; elliottv@ba.ars.usda.gov
Diet and Human Performance Laboratory, Beltsville Human Nutrition Research Center
- **WHAT'S GOOD FOR AMERICANS TO EAT?**
Evelyn Lashley – Supervisory Dietitian, Human Studies Facility
Beltsville Human Nutrition Research Center; lashleye@ba.ars.usda.gov

3. ARS INSTRUMENTATION AND SENSING LABORATORY TOUR

- **RAPID INSPECTING OF FRUITS AND VEGETABLES**
Yud-Ren Chen – Research Leader, Instrumentation and Sensing Laboratory
cheny@ba.ars.usda.gov
- **INSPECTING POULTRY AT 180 BIRDS PER MINUTE!**
Yud-Ren Chen – Research Leader, Instrumentation and Sensing Laboratory



National Restaurant Association Tours and Program October 10, 2006

B. PANEL DISCUSSION (4PM-4:30PM)

ARS NUTRITION, FOOD SAFETY and QUALITY NATIONAL PROGRAMS

- **PANEL CO-CHAIRS**

Joe Spence – ARS Deputy Administrator; joseph.spence@nps.ars.usda.gov

Wanda Collins – ARS / BARC Plant Sciences Institute Director; collinsw@ba.ars.usda.gov

- **PANELISTS**

Jim Lindsay – ARS National Program Leader – Food Safety

Bill Conway – Acting Research Leader, Produce Quality and Safety Laboratory

Dolores Hill – Research Parasitologist, Animal and Parasitic Diseases Laboratory

Alanna Moshfegh – Research Leader, Food Surveys Research Group

Dennis Smith – National Agricultural Library, Food and Nutrition Information Center

Martha Steinbock – ARS Office of Technology Transfer

Bill Rumpler – Research Physiologist

Yud-Ren Chen – Research Leader, Instrumentation and Sensing Laboratory



USDA

January 9, 2014
Beltsville Area
10300 Baltimore Avenue
Beltsville, MD 20705

January 10, 2014
Beltsville Area
10300 Baltimore Avenue
Beltsville, MD 20705

January 10, 2014
(afternoon session)
National Science
Foundation
4201 Wilson Blvd,
Arlington, VA 22230

**National Institute of Food
and Agriculture
and
Agricultural Research Service
Beltsville Area**

**Hispanic-Serving
Institutions
Grants Program
New Project Directors' Training
January 9 -10, 2014**

**100 Years of Agricultural
Research
*Advancing Agriculture through
Research
and Partnership***

Beltsville Area
10300 Baltimore Avenue
Building 005, Room 021
Beltsville, MD 20705

New HSI Project Directors' Training

Day 1

Thursday, January 9, 2014

Beltsville Area, Building 005, Rm 021

8:00 - 8:30 am	Registration (Collect individual lunch orders and payment)
8:30 – 8:45 am	Welcome and Introduction of Committee – Dr. Irma Lawrence, National Program Leader Hispanic-Serving Institutions Education Grants Program
8:45 - 9:15 am	Overview of ARS and Beltsville Area Research, Dr. Steven Shafer, Director, Beltsville Agricultural Research Center
9:15 – 9:30 am	NIFA Dr. Muquarrab A. Qureshi, Assistant Director, Institute of Youth, Family, and Community Dr. Suresh Sivapathasun, Director, Division of Community and Education
9:30 - 10:10 am	Dr. Robert Griesbach, Deputy Assistant Administrator, Office of Technology Transfer, Agricultural Research Service
10:10 - 10:30 am	Morning Break/Networking
10:30 – 10:50 am	Dr. Julie Long, Research Physiologist at ABBL, Beltsville Agricultural Research Center
10:50 - 11:10 am	Dr. Margaret Pooler, Research Leader at Floral and Nursery Plants Research Unit, U. S. National Arboretum
11:10 - 11:30 am	Dr. Dan Shelton, Research Leader at EMFSL, Beltsville Agricultural Research Center
11:30 - 12 noon	Dr. Thomas Wang, Acting Director at Beltsville Human Nutrition Research Center, Representative
12:00 - 1:00 pm	Lunch, Building 005, Room 021
1:00 - 2:00 pm	Building 003, Rm 020 Poster Session (25 posters)
2:00 - 2:30 pm	Building 003, Auditorium Mr. Pedro Nieto – Human Resources Specialist, USDA - Forest Service,
2:30 – 2:45 pm	Closing Remarks– Dr. Allison Yates, BA Associate Director
2:45 pm	Meet the ARS Researchers /Lab Site Visits (7 – 10 per Tour)

Day 2

Friday, January 10, 2014 Beltsville Area, Building 005, Rm 021

8:00 – 8:30 am	Coffee and Refreshments
8:30 – 9:00 am	Dr. Irma Lawrence, Ed. D, HSI National Program Leader, DOCE-NIFA Remarks
9:00 – 9:15 am	Ms. Jacqueline Padron, Diversity and Inclusion Program Manager, USDA
9:15 – 9:30 am	Ms. Wenndy Carrasco, Departmental Student Employment Program Manager, USDA
10:00 – 10:15 am	Ms. Katelyn Sellers, Planning, Accountability & Reporting, NIFA
10:15 – 10:30 am	Dr. Henry Doan, Planning, Accountability & Reporting, NIFA
10:30 – 11:00 am	Ms. Adriene Wooden, Office of Grants and Financial Management, NIFA
11:00 – 11:15 am	Dr. Carlos Blanco, Biotechnology Regulatory Services, Animal Plant Health and Inspection Service, USDA
11:15 – 11:25 am	Mr. Oscar Gonzales, Deputy Assistant Secretary for Administration, USDA
11:25 – 11:35 am	Mr. Elvis Cordova, Chief of Staff, Marketing and Regulatory Programs, USDA
11:35 – 11:45 am	Dr. Irma Lawrence Instructions for the National Science Foundation Visit
11:45 – 12:45 pm	Project Directors transport to National Science Foundation Headquarters - Lunch on Your Own

Students' Tour

Students – Transport to DC for Lunch and Tour

Afternoon at National Science Foundation Headquarters

Stafford Place 2, OISE Room 1155.01

12:55 Arrive at NSF and Go Through Security

(We will begin at 1:00 p.m. promptly at NSF, please be on time)

1:00 - 1:05 pm	Victor Santiago, Division of Human Resource Development Introductions
1:05 – 1:10 pm	Sylvia James, Director, Division of Human Resource Development Welcome and Remarks
1:10 – 1:35 pm	Beth Mitchneck, Division of Human Resource Development ADVANCE: Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers
1:35 – 2:00 pm	Dave Campbell, Division of Research on Learning Innovative Technology Experiences for Students and Teachers (ITEST)
2:00 – 2:25 pm	Katherine Denniston, Division of Undergraduate Education Undergraduate Education Innovation
2:25 – 2:50 pm	John Krupczak, - Division of Undergraduate Education Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM)
2:50 – 3:00 pm	BREAK
3:00 – 3:25 pm	A. James Hicks - Division of Human Resource Development Louis Stokes Alliances for Minority Participation (LSAMP)
3:25 – 3:55 pm	Michael Mishkind – Integrative Organismal Systems, BIO Plant Genome Research Program
3:55 – 4:00 pm	Jermelina Tupas, Deputy Division Director Division of Human Resource Development Wrap-Up
4:30 – 5:00 pm	Comments, Remarks and Adjourn – Dr. Irma Lawrence



Beltsville Area

Dr. Joseph Spence, Director

Mission:

The Beltsville Area consists of ARS programs at the Beltsville Agricultural Research Center and the Beltsville Human Nutrition Research Center in Beltsville, MD; the US National Arboretum in Washington D.C.; and worksites in Chatsworth, NJ; Presque Isle, ME; and McMinnville, TN. BARC is the largest and most diversified agricultural research complex in the world.

Beltsville's record of accomplishments and ongoing programs has made it a world leader in agriculture research. Its international reputation attracts thousands of visitors each year from the United States and abroad.

ARS conducts research to develop and transfer solutions to agricultural problems of high national priority and provide information access and dissemination in order to:

- Ensure high-quality safe food and other agricultural products
- Assess the nutritional needs of Americans
- Sustain a competitive agricultural economy
- Enhance the natural resource base and the environment
- Provide economic opportunities for rural citizens, communities, and society as a whole

Research in the Beltsville Area addresses all of these goals through programs in the Beltsville Agricultural Research Center, the Beltsville Human Nutrition Research Center, and the US National Arboretum.

HISTORY OF THE USDA-ARS HENRY A. WALLACE BELTSVILLE AGRICULTURAL RESEARCH CENTER

For the past century, the historic research facility now known as the Henry A. Wallace Agricultural Research Center, at Beltsville, Maryland, has played an important role in advancing agricultural science and improving people's lives worldwide. During the civil war in 1862, Abraham Lincoln called for the establishment of a Department of Agriculture to improve agricultural production and to better the life of the farmer. Initial studies by the USDA focused on trialing crops for domestic production and to provide information to farmers for increasing productivity.

After the Civil War, thirty-five acres of land lying between 12th and 14th streets and Constitution and Independence Avenues on the National Mall in the District of Columbia was assigned to the Department. At the south end of this land, the Agricultural building was constructed in 1869. A large conservatory for maintaining tropical economic plants was erected next to the building in 1871. Because of an increased need for land to perform plant research, military land in Arlington, Virginia was assigned to the Department in 1902. This facility was known as Arlington Farm Experiment Station.

In 1884, USDA leased land on Benning Road in Washington to build the Veterinary Experimental Station. Expanding programs created a need for a larger and more complex facility. In 1897, the station moved to leased land in Bethesda, MD. The increasing need for an expanded facility, coupled with the high cost of leasing, resulted in Congress authorizing USDA to purchase land for a permanent Station. In 1910, the USDA purchased land at the Walnut Grange plantation in Beltsville, Maryland. Dairy and animal husbandry research were relocated to this site, marking the beginning of BARC. Three years later, the Dairy Barn became the first building to be constructed in BARC and is the site of the first research activity. For the next 20 years, the USDA continued to gradually acquire surrounding land, constructing permanent buildings and small animal and poultry houses.

Prior to 1935, most research programs at the USDA were extension oriented. One of the results of the 1935 Bankhead-Jones Congressional Act was to provide approximately \$10 million toward "research into the laws and principles underlying basic problems of Agriculture in its broadest aspects" (Ling, 1935). Based upon this funding, Secretary of Agriculture Henry A. Wallace moved research projects from experiment stations in surrounding areas to Beltsville, effectively creating the National Agricultural Research Center. The National Agricultural Research Center is now known as the Henry A. Wallace Beltsville Agricultural Research Center (BARC).

Beltsville Agricultural Research Center Beltsville, Maryland

Beltsville Key Areas

- Beltsville Area Administration Building 003
- National Agricultural Library
- National Visitor Center (Log Lodge, Building 302)

Other Key Areas

- USDA Offices George W. Carver Center Sunnyvale Avenue
- Greenbelt Metro Station Metrolink/MARC Trains





PATHWAYS

FOR STUDENTS & RECENT GRADUATES
TO FEDERAL CAREERS



USDA implements the Pathways Programs as a mechanism to recruit, hire, and retain current students and recent graduates. The program's core principle encompasses openness, workforce planning, training and career development, and OPM program oversight. The USDA Pathways Programs has been established to provide students enrolled in a wide variety of educational institutions with opportunities to explore USDA careers while still in school. Current students in an accredited high school, 2 and 4-year college and university; professional, technical, vocational, and trade school; advanced degree program; or other qualifying educational institution and pursuing a qualifying degree or certificate are eligible.

The USDA Internship Program

The USDA Internship Program provides options for paid and unpaid work experience to students who are in high school or pursuing an undergraduate or graduate degree in an accredited college or university (including Home-Schooling, Certificate Programs and Community Colleges). Interns may work during the summer, fall, spring or year round. Please find our current openings and complete an application for the positions in which you are interested by first reviewing the Application then Apply Here!

For additional information, please visit: <https://www.usajobs.gov/StudentsAndGrads> and <http://www.usda.gov/wps/portal/usda/usdahome?navid=pathways>



U.S. National Arboretum



The U.S. National Arboretum is a 446 acre U.S. Department of Agriculture research and education facility and a living museum. It is dedicated to serving the public and improving our environment by developing and promoting improved floral and landscape plants and new technologies through scientific research, educational programs, display gardens, and germplasm conservation. Open Friday-Monday from 8am-5pm. Free admission.

3501 New York Ave. NE
Washington, DC 20002
Phone: (202) 245-2726
www.usna.usda.gov

Acknowledgements



FAR-B is a non-profit organization created to support the research, educational, and outreach activities of the Henry A. Wallace Beltsville Agricultural Research Center (BARC), which is located in Beltsville, Maryland.

BARC is the centerpiece of the Agricultural Research Service (ARS) - the primary research arm of the U.S. Department of Agriculture. BARC has an outstanding international reputation for cutting-edge research in many areas of food and agriculture.

FAR-B membership includes USDA alumni, BARC employees, individuals or groups from academia, industry, or government, and the general public.

FAR-B GOALS

- Disseminate information regarding unique expertise of BARC scientists and their research accomplishments that benefit society.
- Organize, sponsor and finance major symposia, field days, and scientific seminars.
- Generate funds to upgrade research equipment and facilities.
- Present information and expert testimony to the U.S. Congress and others to enhance funding for BARC.
- Present to local students educational programs that focus on outstanding research conducted at BARC.
- Provide Travel Grant funds to BARC scientists for travel to cooperating laboratories and professional meetings when finances permit.

Dr. James Anderson,
FAR-B President

Special Thank You's to

The Beltsville Area Diversity Taskforce – Leadership Advisory Subcommittee and National Institute of Food and Agriculture

Martha Tomecek, Chairperson of BADTF

Jenny Allen

Verneta Gaskins

Irma Lawrence, NIFA

Josue Lopez, NIFA

Gloria Solano-Aguilar

Tanya Zastrow

Monica Santin-Duran

(BADTF – Beltsville Area Diversity Task Force)

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.



F A R - B
FRIENDS OF AGRICULTURAL RESEARCH - BELTSVILLE, INC.
P.O. BOX 1061
BELTSVILLE, MARYLAND 20704-1061
www.far-b.org

Dedicated to Promote the Research and Education Programs of the Henry A. Wallace
Beltsville Agricultural Research Center (BARC), Beltsville, Maryland

June 28, 2012

Attention:

Allison Yates,
Beltsville Area Associate Director
ARS/USDA
10300 Baltimore Ave.
Beltsville, MD 20705

FAR-B requests reimbursement for the \$850 deposit paid for by FAR-B on 1/26/2012 that is applied to an ARS dinner meeting at the Holiday Inn BEO # 11296 (see attached Banquet Event Order for the function, and attached receipt of the deposit by the Holiday Inn).

Please remit a check in the amount of \$850 to

FAR-B
Friends of Agricultural Research-Beltsville, Inc.,
P.O. Box 1061
Beltsville, MD 20704-1061.

FAR-B is a non-profit organization incorporated under the laws of Maryland.

Sincerely,

James D. Anderson, President
FAR-B



June 28, 2012

Attention:

Allison Yip
Bettsville Area Resource Director
ARBA/ARCA
10300 Baltimore Ave.
Baltimore, MD 20705

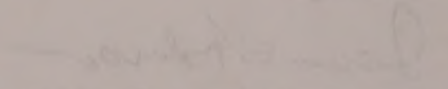
FAR-B requests reimbursement for the \$550 deposit paid for by FAR-B on 1/25/2012 that is applied to an ARS dinner meeting at the Holiday Inn DCU & 1200 (see attached Budget & an Order for the dinner and attached receipt of the deposit by the Holiday Inn).

Please remit a check in the amount of \$550 to:

FAR-B
Friends of Agricultural Research - Bettsville, Inc.
P.O. Box 1081
Bettsville, MD 20704-1081

FAR-B is a non-profit organization incorporated under the laws of Maryland.

Sincerely,

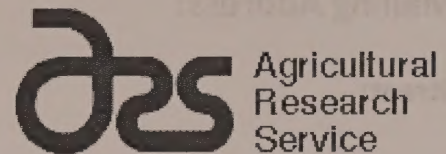
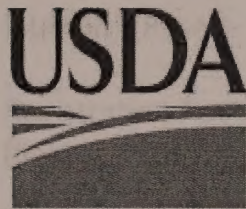

James D. Anderson, President
FAR-B



**BARD-sponsored Workshop:
Microarrays and Next-Generation Sequencing for
Detection and Identification of Plant Viruses**

**The United States - Israel
Binational Agricultural Research and Development Fund**

Thursday, November 17 – Saturday November 19, 2011



Beltsville Agricultural Research Center
10300 Baltimore Avenue, Beltsville, Maryland 20705-2350

The goals of this Workshop are to bring together those who have experience with different microarray, macroarray, and next-generation sequencing systems as applied to the detection and identification of plant viruses, with special emphasis on the application of these methods to identify new and emerging viruses. Dissemination of knowledge regarding improved means of detecting, identifying, and characterizing such new and emerging viruses is critical to preventing the introduction of new diseases into other areas through legitimate international trade. The Workshop will critically review current approaches to microarrays and next-generation sequencing in order to identify the most promising methods, the bioinformatic challenges, critical deficiencies, and areas in which collaborative efforts may move the field forward. Discussion of ways to make these technologies more cost-effective for routine use by plant protection services will be incorporated into the Workshop structure.

Registration Form

NOTE: Attendance at this Workshop is limited by the facilities available. Only those who have been invited to participate, or who have pre-registered with the organizers, may register. To determine whether any additional openings are available, please contact John Hammond (john.hammond@ars.usda.gov)

Instructions

[Highlighted items are Required Fields]

Name:

Last:

First:

Other:

Institution/Affiliation:

Mailing Address:

Street:

City:

State:

Zip/Postal Code:

Country:

Electronic Contacts:

Telephone:

Fax:

E-mail address:

Posters:

Will you be presenting a poster? ☐ Yes ☐ No

Title of Poster:

Abstract Preparation Instructions [[link to the 'Abstract Preparation Instructions'](#) shown below]

Send abstract with subject heading "BARD Workshop Abstract" to:

john.hammond@ars.usda.gov

Registration fee

Registration fees cover conference documents, coffee breaks, and lunches during the Workshop. The registration fee is \$125 for all participants; in the event that a registrant is unable to attend, the submitted registration fee will be refunded less a \$20 administrative fee provided that the organizers are notified at least one week prior to the Workshop. Please click on the link to the registration fee submission site

[Submit] [Reset]

Registration Fee Submission Site

[link]

Registration will not be complete without payment.

Registration Confirmation

Confirmation of registration will be sent **ONLY** by e-mail. If you do not include an e-mail address, we will not send confirmation of your registration.

Target Audience (-100 from the current population)

- Local government and community organizations
- State and federal agencies and non-profit organizations
- College students, graduate students, and postgraduate students
- Non-profit organizations and community groups

Workshop Overview

8:00 Open for Registration
8:30 Welcome and Workshop Overview - Gary Allen
9:45 Congressional Welcome

10:00 - 12:15 Morning Theme: Transitioning to a Low Carbon Economy in the Mid-Atlantic
Washington area

1:00 - 1:45 Climate Change Impacts on Forests in the Mid-Atlantic Region
John Hogg Deputy Program Manager, Northern Global Change
Research Program, US Forest Service (on video)

[link from '[Abstract Preparation Instructions](#)']

Posters must fit on a 46"x 70" (H x W) surface. Poster boards are pushpin-compatible.

Preparation of Abstracts

1. Abstracts should be formatted is 12-point, Times New Roman font and preferably in Microsoft Word format.
2. The top and side margins should all be one inch; please justify the right margin.
3. The Title should begin on line 1 in boldface caps; italicize any species names.
4. Leave one blank line. Then type the authors' names - first name, middle initial and last name. The presenting author should be identified with an asterisk (*).
5. Leave one blank line. Then type the authors' addresses. For multiple affiliations, use superscripts to associate authors and institutions.
6. Leave one blank line. Begin the Abstract text on a new line with no indent; limit the text to no more than 30 single-spaced lines. Italicize any species names.
7. No figures, columns, or tables, please.
8. The abstract should be informative and understandable. It should present what is important in the poster, moving from an introductory statement of the rationale and objectives or hypotheses, through materials and methods, to emphasize results, conclusions, and impact. The abstract should stand alone; do not deflect the reader with promises such as "will be discussed" or "will be explained." Limit use of abbreviations, and define any abbreviations used.

[see [Abstract example.pdf](#) (link)]

Threats to Urban Forest Ecosystems

2nd Annual Workshop Hosted by the Baltimore-Washington Partnership for Forest Stewardship

October 28, 2010

Patuxent Wildlife Visitors Center

Scarlet Tanager Loop, Laurel MD

<http://www.fws.gov/northeast/patuxent/vcdefault.html>

Objective and Purpose:

- To describe the varied threats to the critical urban and nearby forests in the Baltimore-Washington corridor, including development to accommodate an increasing population, harmful effects of deer overpopulation, stresses amplified by climate change, and the resulting impacts on human health.
- To highlight a range of approaches to maintain forest cover and health in the face of these threats. A strategic and comprehensive response is necessary to ensure that these ecosystems continue to provide the natural services that support a healthy Chesapeake Bay, provide human health and recreational benefits, and enhance regional biodiversity.
- This workshop makes the case for the critical importance of trees and forest resources in preserving a livable, vibrant, and healthy environment.
- BWPFS is a unique collaboration among federal and State agencies and a NGO, working together, to promote healthy forests, and is seeking to expand these efforts to other interested partners.

Target Audience (~100 from BW corridor communities):

- Local governments and municipalities with land management responsibilities
- State and federal agencies that own and manage land within the region or can provide technical and financial resources for meeting natural resource goals
- Citizen advocacy groups, Forestry Boards and watershed organizations
- Non-profit environmental organizations and private sector businesses

Workshop Overview:

9:00 Open for Registration
9:30 Welcome and Workshop Overview – Gary Allen
9:45 Congressional Welcome

10:00 - 12:15 Morning Theme: Threats to Forest Ecosystems in the Baltimore-Washington area

10:00-10:25 Climate change impacts on Forests in the Mid-Atlantic Region
 John Hom, Deputy Program Manager, Northern Global Changes
 Research Program, US Forest Service (confirmed)

<http://www.fs.fed.us/ne/global/index.html>

- 10:25-10:50 Urban Heat Islands and Human Health
Russ Dickerson, University of Maryland (confirmed)
<http://www.atmos.umd.edu/~russ/>
- 10:50-11:00 Break
- 11:00-11:25 Assessing Ecological Systems in Urban Areas
Mike Galvin, Casey Trees (confirmed)
<http://www.caseytrees.org/>
- 11:25- 11:50 Urban forest management and coordination
Anne Draddy, TreeBaltimore, Coordinator for Baltimore (confirmed)
3001 East Drive, Baltimore
<http://baltimorecity.gov/Default.aspx?TabID=454>
- 11:50-12:15 Discussion, question and answer with four speakers on panel
- 12:15 – 1:00 Lunch
- 1:00-3:30 **Afternoon Theme: Assessment and Response: What we can do**
- 1:00-1:25 Assessment of Local Forest Canopy in Mid-Atlantic Region
Jarlath O'Neill-Dunne University of Vermont (confirmed)
<http://www.uvm.edu/~joneildu/>
- 1:25-1:50 Sustainable sites and sustainable development
Jeffrey Popp, Land Restoration Program Manager
Wildlife Habitat Council (confirmed)
<http://www.wildlifehc.org/>
- 1:50-2:00 Break
- 2:00-2:30 The impact of Deer on Forest Ecosystems
Scott Bates
NCR-NPS Wildlife Biologist (confirmed)
<http://www.nps.gov/cue/wildlife/index.htm>
- 2:30-3:00 Development and Population Expansion in the Baltimore-Washington Region
Paul Desjardin, Director of Community Planning and Services (Confirmed)

Metropolitan Washington Council of Governments

<http://www.mwcog.org/>

3:00-3:30 Discussion and questions to the four speaker panel

3:30-4:00 What can you do now? Resources and links and Close Request for Feedback (forms)

Christine Conn, Maryland DNR and co-Chair BWPFS

The Baltimore Washington Partners for Forest Stewardship

Natural lands serving the needs of people...

The frontier of ecology is no longer found in our rural or wilderness areas. Our most sensitive environments are those areas impacted by our accommodation to the growing human population and need for economic opportunity. The vast majority of us live in cities, towns and suburban areas where people yearn for some contact with nature as a defining feature of their community and a needed benefit for the quality of their daily lives. Recognizing and preserving the ecological services and wildlife habitat provided by our natural areas has become a critical consideration in the design of our cities, neighborhoods and places of employment.

These lands must be cared for...

The last remaining natural landscapes and forested ecosystems, within the Baltimore Washington Metropolitan corridor are increasingly essential in the provision of ecological services for our health, land, climate, wildlife and the life sustaining capabilities of the Chesapeake Bay, especially in the face of increasing development pressures and a changing climate. This natural heirloom will continue to enrich our lives if we collaborate to preserve it, better understand its value and learn to delight in its myriad bounties. For this ecology to remain viable, however, we must apply our best science, information and expertise to guide our decisions in the stewardship and protection of this land.

The Baltimore Washington Partners for Forest Stewardship (BWPFS) is a call-to-action for all land managers to work together...

The Partnership provides a landscape-level perspective to coordinate management and restoration activities and applied research studies among four Federal landowners in the highly urbanized Baltimore-Washington corridor. Through these efforts, the Partnership seeks to improve the ecological services of their natural landscapes and forested ecosystems and reduce the environmental impacts of their land and facility management activities to a greater degree by working together, rather than on an individual basis. The Partnership will seek out stakeholders in the region to forge other complementary management efforts, using this initiative as momentum.

Current Partnership Land Resources...

Of the 25,660 acres (40 square miles) of land managed by existing partner agencies, over 64% of the land area supports forests (13,270 acres) and wetlands (3,230 acres). The landscape surrounding the facilities is one of intense population growth and associated urban development. These lands represent one of the last remaining large contiguous blocks of urban forest land, are critical elements of the region's Green Infrastructure network and provide irreplaceable water quality, air quality and living resources support services to the Baltimore-Washington metropolitan region.

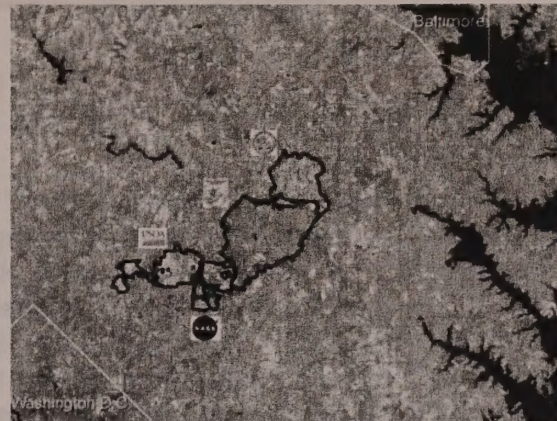
Expanding the Partnership

BWPFS is actively seeking new partners, in both the private and public sectors of land managers, to expand the collaborative efforts for protecting the ecological services of these lands today and for future generation.

Baltimore Washington Partners for Forest Stewardship

The Baltimore Washington Partners for Forest Stewardship (BWPFS) is a collaborative of federal landowners, who have joined with the **Maryland Department of Natural Resources** and the **Center for Chesapeake Communities** to promote collaborative strategies for the restoration, conservation and stewardship of shared forested ecosystems and managed lands in the Baltimore Washington corridor. BWPFS was formed in 2006 through a Memorandum of Agreement, signed by each organization's Executive Leadership. The federal partners include:

- **USDA Beltsville Agricultural Research Center;**
- **US Army Fort George G. Meade,**
- **NASA/Goddard Space Flight Center and**
- **USFWS Patuxent Research Refuge.**



Together, partner agencies own and manage about 25,660 acres (40 square miles); over 64% of the area is either forested (13,270 acres) or wetlands (3,230 acres). These unique ecological resources are among the last significant Green Infrastructure resources in this highly urbanized region. BWPFS works to collectively manage, restore and conserve these natural landscapes that are important for supporting a healthy and diverse forest ecosystem, reducing Chesapeake Bay water pollution, providing public recreational and educational opportunities and supplying important public healthy benefits such as clean air and water. The partnership leverages the research and scientific expertise of its members to address management issues at these facilities and lands and works together to achieve a greater and more effective benefit.

BWPFS is highlighted as a Federal agency "Leading by Example" pilot project in the Chesapeake Bay Program's Farm and Forests Initiative response to the CB Executive Order. The Partnership is offering expanded membership this year to other governmental partners including the National Park Service, U.S. Department of Homeland Security, DOD National Security Agency, US Geological Survey, US Forest Service, Food and Drug Administration, University of Maryland, MNCPPC, and the cities of Greenbelt, Bowie and Laurel.

MD & VA

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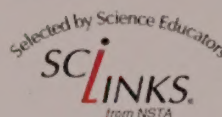
*... 144 Years of Ag Research*

History of Research at the U.S. Department of Agriculture and Agricultural Research Service

Tripping the Light Switch Fantastic

[Back to Features](#)

ARS botanist Harry A. Borthwick helped discover the plant photoreceptor protein called phytochrome.



In 1918, a pair of U.S. Department of Agriculture scientists in northern Virginia asked two simple questions, launching an intellectual voyage still far from over. Their discoveries were the prelude to the search for what would prove to be one of nature's most important light switches. During the years 1936 to 1959, a dozen scientists at USDA's research center in Beltsville, Maryland, pursued and finally forced their quarry, phytochrome, into the daylight.

Today we know that phytochrome is a dual-form plant protein. It is switched back and forth by red light and by far-red, a zone at the horizon of our eyes' visual limits. By this transformation, phytochrome ordains whether a plant will start, or put off, making flowers. And in the next season, phytochrome wakens seeds to germinate or prolongs their sleep.

Skeptics, who reasonably believed phytochrome an illusion, dubbed it a "pigment of the imagination." Ironically, imagination was the key to unveiling phytochrome. It showed itself in clues the scientists saw in phytochrome's reflected reality—the measured life cycle of plants.

Balky Tobacco, Bullheaded Soybeans

The search began in 1918. Why, wondered botanist Harry A. Allard and physiologist Wightman W. Garner, did Maryland Mammoth tobacco not know when to stop making leaves and start making flowers and seeds?

View related stories:[Enzymes Give Plants UV Protection](#)[New Clue About Plants' Sunlight Sensors Revealed](#)

The tobacco, first noticed in 1906, seemed a boon to growers. It grew as tall as 15 feet and put out nearly 100 leaves until frost would kill it. But what good was this oddity? It rarely flowered in Maryland, and it never produced seed in the field that could be used to plant the next crop. Its tantalizing ability to produce leaves seemed a mirage.

And why, Garner and Allard puzzled, were soybean farmers being frustrated at spreading out their harvest time? They would plant the crop 2 weeks apart, but the plants would all set flowers at the same time.

The two researchers solved both mysteries with the same experiment. In retrospect, the test seems so simple it might have sprung from the naive fancy of a child—except no one had tried it before.

In July 1918, Allard and Garner grew some Biloxi soybeans and Maryland Mammoth in pots. Some plants they left outside all day long. But every afternoon, they placed one group in a shed without windows, returning them outdoors the next morning.

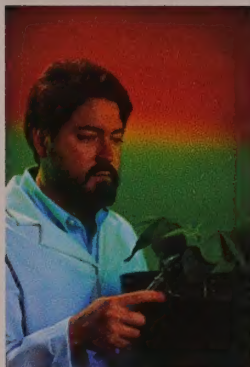
The tobacco flowered 3 months earlier; the soybeans, 5 weeks earlier. Thus was born the concept of photoperiodism—an organism's response to the relative lengths of night and day.

At the time, the light/dark ratio lay mostly unexplored, an oddity in the standard explanation that plants grew and developed by laws of soil, climate, and the total amount of light they received.

The two USDA scientists soon found that different plants had different kinds of photoperiods. Maryland Mammoth and Biloxi soybeans, as well as chrysanthemums and others, flower in reply to the shortening days of late summer.

Lettuce, spinach, and the like are long-day early summer—flowerers. And day-neutral plants like tomatoes and dandelions flower right up until frost.

People didn't wait to learn what made photoperiodism work; they used it. Florists, no longer chained to a plant's outdoor season, began growing flowers indoors year round, serving each type the ration of light it needed to yield flowers. Plant breeders came out with crop varieties suited to day length, as fixed by the angle that a given latitude presented to the sun during a given season. Seed of Maryland Mammoth was



Continuing phytochrome studies at the Beltsville (Maryland) Agricultural Research Center, plant physiologist Steve Britz measures horizontal light flux in a soybean canopy with a quantum sensor to assess the effects of shading.

successfully grown in Florida, where the plant flowered and set seed in the state's brief, mild days of winter.

It would take 41 years to isolate phytochrome—to get, in the words of Sterling B. Hendricks, “a bottle of the stuff” that was the trigger for photoperiodic response.

Night Lightening

In 1936, with little fanfare, USDA established a tiny research project on photoperiodism at its sprawling research center in Beltsville.

Botanist Harry A. Borthwick—heading the project—and physiologist Marion W. Parker were unsatisfied with using the conspicuous arrival of flowers as a meter of photoperiodism. Instead they examined “primordia.” These microscopic bodies emerge as the first visible signs of flowers.

They quickly discovered that only 2 “short” days—when nights were as long as 10-1/2 hours—made Biloxi soybeans produce primordia 5 days later.

Shortly thereafter, they found that this flowering could be prevented if a single, 30-second burst of light butted in on the long night. How could something so seemingly trivial—hardly enough light to wake a sleeping child—halt a plant's charge toward reproduction?

Again there was no answer, but breeders and horticulturists quickly enjoyed savings on light bills for their greenhouses. Instead of leaving the lights on for several hours each night to create a short night, they used a few minutes of light to get the same result.

At the time, the major focus of photoperiodism studies was to look for some kind of signal—perhaps a hormone—that travels from a plant's leaves to its fast-growing tips. But about 1940, Borthwick and Parker saw that they should home in on the leaf's interplay with light itself. About leaves, they knew much; they needed someone who knew about light.

The Disguise Takes on Color

They sought out Hendricks, a Beltsville colleague. An expert mountain climber, Linus Pauling's first grad student, and a brilliant chemist, Hendricks was one of the first Americans to use x-rays to study molecular structure.



Engineer Karl Norris displays the dual monochromator spectrophotometer which made history with its rapid and precise assays of phytochrome.

The trio knew their quarry had to be a substance that could detect whether light was present. So it must be a pigment. But sunlight comes in a spectral stew of visible and invisible tints. Which color ingredient energized their phantom pigment? And how could they find it?

Theoretically, the solution was simple. Just as water droplets carve the sun's rays into an arching rainbow, the scientists used a prism to filter light into its separate facets.

Hendricks knew how spectrographs worked and how to tinker with them. But most spectrographic work dealt with purified material, not the queer confederacy of solids and liquids that makes up leaves. Further, the light intensities used in spectrographs were small—designed for the needs of photographic film, not living plants. Finally, the spectra would have to be spread over a wide area; the researchers would gain nothing if several colors fell on the same leaf.

The solution was a \$50 experiment so elegant no large-scale research effort would ever have devised it. Their huge, 10-kilowatt carbon arc-light was “cadged from a Baltimore movie theater, with memories of pulchritude,” Hendricks reported later.

And somehow he obtained two large prisms, which were already historic. They'd been used by Samuel Pierpont Langley. Astronomer, physicist, and aeronautics pioneer, Langley had died in 1906.

For their test, light passed through the prisms to cast its spectrum 42 feet away, in a 7-foot swath, across 14 soybean plants at a time.

Several groups of plants had been grown on 16-hour days to prevent flowering; each plant had been stripped of all but one leaf—the youngest mature one. When the test began, the scientists cut the plants' ordinary light exposure to 10 hours a day, which normally would induce flowering. But in the middle of the dark period, they turned on the spectral array for periods of 1 to 25 minutes.

After 6 days, they returned all the plants to long photoperiods. A week later they checked for primordia. The fewer the primordia, the greater the effect of specific light spectra on the pigment.

With this test, the pigment surrendered the first solid clue to its color. Since the plants responded most strongly to red and yellow

light, the pigment must be absorbing these hues. And that meant the active form of the pigment had to be blue or green.

This conclusion, obvious to any student of light, may not be clear to a lay reader. Any color that we see is made up of some combination of any or all of the red, yellow, green, and blue zones of the visible spectrum. Like a selective mirror, a colored substance reflects only what it cannot absorb. So something—like phytochrome—that absorbs only reds and yellows will reflect blue and green.

In 1948, tests with barley—a long-day species—proved that the same pigment governed flowering in long- as well as short-day plants. This too was exciting, but a couple of years later the outlook seemed clouded. The spectrograph tests were important, but also awkward, imprecise, and time consuming.

Next to the spectrograph room was a doorway that would lead Hendricks, Borwick, and Parker to faster progress.



Photosynthesis taking place in wheat plants can be measured in field chambers like this one being adjusted by plant physiologist Richard Garcia.

Red and Far-Red Switchcraft

The door belonged to the Seeds Investigations Laboratory. There, the husband-and-wife team of Eben H. and Vivian K. Toole had for years been looking into why some seeds, like lettuce, need light to germinate.

Some 15 years earlier, physiologist Lewis H. Flint, another researcher in the lab, and E.D. McAlister of the Smithsonian Institution had set about finding that, indeed, germination was promoted most by red light.

Maybe that would be useful, Eben Toole mentioned to the photoperiodism group sometime in 1951 or 1952.

Would it ever! Experiments would take days instead of weeks. Moisten the seed for 16 hours, hit it with red light, then watch for germination in a few days.

Further, Flint and McAlister had seen something intriguing about far-red light and germination. Far-red light not only failed to promote germination; it stalled it. Hendricks, Borthwick, and Parker hadn't seen this—but it would also turn out to be true—in flowering. Discovering that far-red and red somehow foiled one another was critical in all further work to get a grip on the pigment.

On April 9, 1952, the loose-knit team of scientists came up with another magnificently simple find. Seed hit with red light germinated unless it was then hit with far-red; but if red again ensued, it would germinate. Incredibly, all that mattered was which color came last even if the seed was struck by 100 alternating cycles of red and far-red.

That summer, the researchers confirmed the same switchability in flowering. Test plants flowered only if far-red light ended the sequence.

While fascinating, these discoveries gave the team no hard facts about the pigment's chemistry or its levels inside leaves. But they had reasoned this out: Their studies showed the pigment was probably blue or green and far more strongly colored than chlorophyll.

There was another clue: albino barley plants, while responsive to their light tests, showed no blue tinge. That meant the pigment's concentration was minuscule. To cause such dramatic effects on plants, the stuff had to be some kind of catalyst.

That, they surmised, meant it was an enzyme—and therefore a protein.

Still, though they could measure what the receptor protein did in plants, they couldn't detect it in a test tube. And virtually no one else was doing this kind of work; literature searches circled them back to what they had published themselves.

By 1953, Flint and Parker had left the team. But Borthwick, Hendricks, and the Tooles were soon joined by two physiologists, Albert A. Piringer and Robert J. Downs.

Then, around 1956, a third phase of informal collaboration with colleagues led the team to one final breakthrough.

A Bottle of the Stuff

Agricultural engineer Karl H. Norris, who at the time headed up a USDA Agricultural Marketing Service lab, had worked for about 10 years on nondestructive ways to gauge the quality of produce.

To do this, he'd adapted several spectrophotometers so they would measure typical patterns of light absorption by goods such as eggs and apples. Ordinarily, these gadgets required material that was nearly transparent.

Joining Norris in 1956 was biophysicist Warren L. Butler; 1957 saw the final ingredient added, when Borthwick brought aboard Harold W. Siegelman, horticulturist turned biochemist.

That same year, the project received its first-ever operating budget, when Borthwick's lab was named one of ARS' two Pioneering Research Laboratories—the other being Hendricks' mineral nutrition lab.

The basic idea was to use the spectrophotometer to tally changes in light absorption by plant tissue that held the pigment protein. The researchers knew that red changed the protein into a form sensitive to far-red. So, that form (which turned out to be green pigmented) should absorb more far-red light than red. And vice versa: Far-red light should make the now red-sensitive (blue) form of the protein absorb more red than far-red.

For 2 more years, the team tried tissues from various plants: lettuce, cocklebur, albino barley, and the like. None worked.

In mid-June 1959, Hendricks showed up in Butler's lab with dark-grown turnip seedlings for the spectrophotometer. "To our amazement and delight, mixed with skepticism," Butler later reported, "we found that the difference spectrum between the red and far-red irradiated sample was precisely that predicted for phytochrome by the physiological action spectra" the scientists had been charting for years with Hendricks' large spectrograph.

Within 2 hours, Siegelman tried the technique with a sample of ground-up turnip seedling. It retained the red/far-red reversibility.

He then boiled a sample and tested it: no reversibility. This agreed with the prediction that the receptor was a protein, now destroyed by boiling.

Officially Named

The following April, the stuff in the bottle had its official name, a borrowed one combining the Greek words for *plant* and *color*. Butler suggested it half-jokingly, according to Borthwick. Phytochrome, which had once referred to all visible plant pigments, now named a dual-form protein—green in its red-sensitive form, blue when sensitive to far-red.

Later that summer, Hendricks was invited to speak in Montreal at the Ninth International Botanical Congress. He suggested Butler run a demonstration after his talk. Norris produced a portable photometer, rigged to a wall-clock-size meter.

In repeated trials in Beltsville, the meter's dial swung reliably between its 9-o'clock and 3-o'clock positions each time a sample was alternately beamed with red and far-red light.

With high confidence, Hendricks, Butler, and Siegelman set off by car for Montreal. Unfortunately, they did not yet know that the far-red form of phytochrome is unstable once red light produces it in a seedling. This insight came too late to prevent their Montreal demonstration from becoming a dud.

Whenever the three scientists stopped for gas during the drive to Canada, someone would check the trunk to make sure the corn seedling samples were okay. But opening the trunk let in huge doses of red light, converting the red-absorbing form of the protein into the wobbly, far-red form. By the time they got to Montreal, the seedlings didn't hold enough phytochrome to nudge the photometer dial by one whit.

"However," Butler remembered later, "in spite of the failure, the audience appeared to be kind and accepting and even to believe that we probably had achieved what we claimed."

Since 1959, phytochrome has continued to resist scientific prying. Not until 1983 was a reliable means developed to purify the protein in a fully intact form.

It's still unclear where phytochrome resides in cells and exactly how it throws its genetic and behavioral switches in a plant.

It's not even absolutely settled whether the far-red-sensitive form of phytochrome is an enzymatic protein. A catalyst, yes, but not all catalysts are enzymes. Phytochrome, like some other plant proteins, may have a different way of filling its role as a biochemical amplifier.

In addition to phytochrome, scientists have uncovered two or three other classes of photoreceptors, such as those that absorb blue light and possibly even ultraviolet light.

Researchers today continue gathering and sifting clues that may open up secrets of phytochrome and other photoreceptors for human advantage. What may emerge could

be new strategies to control weeds, to make better use of a crop plant's preference for certain shades of light, and to use biotechnologies to improve one plant by borrowing the genetic light switch from another.

Such stories cannot yet be written in full, but their outlines are being imagined.—By Jim De Quattro, ARS.

"Tripping the Light Switch Fantastic" was published in the September 1991 issue of *Agricultural Research* magazine.

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BACKGROUND

The Controlled Environment Facility is the latest accomplishment in the modernization of the Beltsville Agricultural Research Center (BARC) and provides a central site for state-of-the-art growth chambers that will benefit numerous research units. Many problems in agricultural research require raising and studying plants in closely regulated environments and strict isolation because of pathogens or for genetic engineering. Some projects need material produced under identical conditions on a year-round basis. Other projects study plant responses to environmental variables, such as humidity, temperature, atmospheric carbon dioxide or light quality, that are difficult to manipulate in the field or in greenhouses.

BARC was among the first agricultural research centers to utilize controlled environment chambers for plants and has a long tradition of innovative research in this area. Controlled environment chambers have become increasingly sophisticated and expensive. For example, computerized systems monitor and control environment variables more precisely and high-intensity lighting systems reproduce sunlight more accurately. Closer simulation of the natural environment is needed to conduct meaningful studies on environmental problems, ranging from the adaptation of plants to rising atmospheric carbon dioxide to uncovering mechanisms of resistance to drought and air pollution. The Controlled Environment Facility will provide a series of staged chillers to circulate cold ethylene glycol solutions for chamber cooling, eliminating the need for each chamber to have its own compressor, enhancing reliability and increasing energy efficiency. Standardization of chamber design will ease maintenance and increase sharing resources. The new complex provides rooms for pesticide mixing and application, plant potting and harvesting, an office to house the computer monitoring equipment, and has direct access to adjacent renovated greenhouses and the Horticultural Sciences Building.

Andy Quinn
Hoyer's Staff, BARC
Hoyer's Staff, BARC

DEDICATION CEREMONY for the

Beltsville Agricultural Research Center's

CONTROLLED ENVIRONMENT FACILITY \$4.3 million

10:00... Phyllis E. Johnson - Welcome
Director, Beltsville Area

Floyd P. Horn
Administrator, ARS

Steny H. Hoyer
U.S. Congressman

Ribbon Cutting Ceremony

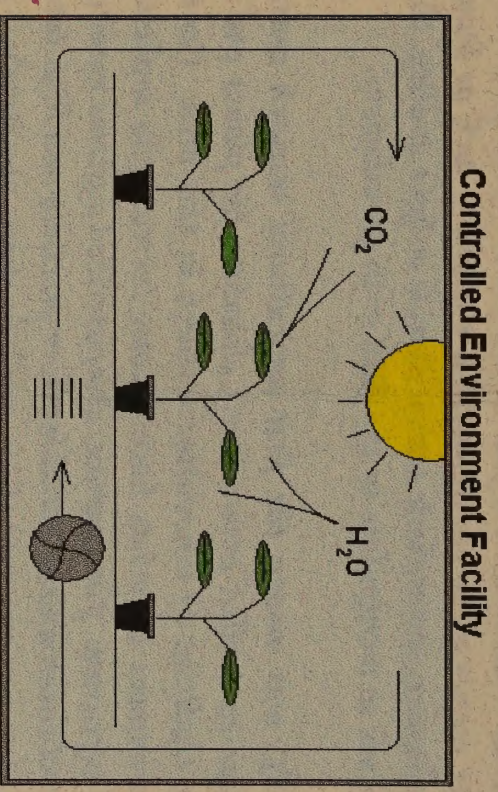
Tour of the Controlled
Environment Facility

Following the Ceremony, light refreshments will be served.



WELCOME TO THE

United States Department of Agriculture
Agricultural Research Service
Beltsville Agricultural Research Center



DEDICATION CEREMONY

September 14, 1998
Building 010B, BARC-West
10:00 a.m.